POWER PLANT ENGINEERING

Established Over 29 Years

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Between the Dragon's Eyes

WHEN YOU first glance at this picture, you may imagine for an instant that you are looking straight into the glittering, ferocious eyes of some weird, prehistoric monster. Perhaps it is a dragon, that beast of prey so dear to the imagination of the Middle Ages, celebrated in legend, song and story, and well known to us in the tale of St. George, which we read when we were boys. And there, seated calmly on the bridge of the dragon's nose, is a group of men! One flick of that long, fiery tongue and they will be swallowed up!

Closer examination of the picture, however, soon dispels this fanciful illusion and you see that these men are sitting in a concrete-lined tunnel. This is, in fact, the 11,000-ft. tunnel, 21½ ft. in diameter with three 12-ft. penstock openings leading from it, serving the Skagit River hydro-electric plant. On page 638 of this issue, you will find more information about tunnels, penstocks and surge tanks, and a discussion of recent practice in applying both impulse and reaction types of hydraulic turbines to high heads.

"DON'T GET EXCITED" is a good motto for all power plant operators. But the power plant itself cannot operate unless one thing in it is excited—the main generating unit. On page 645 of this issue appears a complete and authoritative discussion of exciters and of the various methods used in up-to-date plants for driving them and for connecting them to the electrical system.

FIRST UNIT OF 200,000-KW. PLANT FOR LOS ANGELES GAS AND ELECTRIC CORPORATION

IN 1923, the maximum capacity of the Alameda St. Station of the Los Angeles Gas and Electric Corporation was reached, with the installation of the last unit for which space was available. This station is operated with cooling towers. In seeking a site for a power development to take care of future requirements of the system, the desirability of avoiding the use of cooling towers and securing a proper supply of water for the condensers led to the selection of Seal Beach as the location for the new power station. This site is approximately 30 mi. from the business center of Los Angeles, and is the most desirable one which was available for this type of development.

Rights of way were secured for transmission lines into the City of Los Angeles, the overhead lines being carried across country for part of the distance, then following the river bank to the substation at 25th St., Los Angeles, as shown in Fig. 1. The plant is so located as to be conveniently accessible for fuel supply, both oil and gas. Some problems had to be met in combating the influence of the salt fogs and southwesterly storms, but these were solved in what is believed to be an effectual manner.

LOCATION AND BUILDING

Sub-soil is excellent for foundation purposes so that only the wall of one side of the station and the intake screen house had to be supported on piles. The location is ideal in that it is upon a point of land lying between Alamitos Bay and the Pacific Ocean, hence it was possible to arrange the condensing water intake on the bay side and the discharge toward the ocean, so that there is little possibility of recirculation of the condensing water. The sea water temperatures are fairly constant, ranging between a minimum of 55 deg. and a maximum of 75 deg.

As at present constructed, the building is of sufficient size to house two generating units and six boilers, with the necessary auxiliaries and electrical equipment. The first installation, which is about to be placed in service, consists, as shown in Fig. 2, of one unit, nominally rated at 30,000 kw. but which experience has shown can conservatively carry 35,000 kw. at 80 per cent power factor, together with three boilers, necessary auxiliaries and electrical equipment. The ultimate design, as at present contemplated, will have a total capacity of 200,000 kw. This will comprise six generating units and eighteen boilers, the plant being extended lengthwise as capacity is needed.

OIL FUEL SYSTEM

About 1000 ft. from the power station a fuel oil tank of 55,000 bbl. capacity was constructed. This tank is connected through well housed pumping equipment with two service tanks located underground just outside the boiler room wall, each tank having a capacity of 2000 bbl. A 16-in. natural gas main is also carried into the station. Within the boiler house the fuel oil system consists of a circulating ring, fed with oil through a system of heaters supplied with steam in part from the exhaust of the turbine-driven fuel oil pumps, and from the high temperature heater with steam from the boilers which is desuperheated. The temperature of the oil is maintained constant by means of thermostatic control on the steam feed to the high temperature heaters, and the oil pressure is maintained at a suitable value by proper pressure control valves.

Detail of the fuel oil system is shown in Fig. 3. From the service oil tank, the oil is drawn by turbo oil pumps and delivered to the coolers, relief valves allowing excess oil to return to the suction intakes. In the coolers the oil is heated by condensate drawn from the receiver tank,

which receives its supply from the condensers, heaters and desuperheater, and is carried at 25 lb. absolute. Water from the coolers passes through a syphon to an oil separating tank, thence to the water tank, excess being blown down as waste. From the coolers, oil passes to the condensers, which are heated by exhaust steam from the turbo oil pumps, thence to heaters which take saturated steam at 350 lb. direct from the desuperheater. Supply of this high-pressure steam is regulated by thermostatic tubes in the oil outlets from the condensers governing thermostatic valves in the steam supply lines to the condensers. Oil pressure is governed by regulating valves in the steam lines to the oil pumps, controlled by pressure in the oil discharge from those pumps.

Desuperheating is accomplished, under thermostatic control, by boiler feed water at 360 deg., condensate from the desuperheater and from the separator, which is alongside, being taken to the receiver tank.

From the heaters, oil flows to the oil loops, one for each three boilers, thence to burner loops, one for each boiler.

Excess pressure on the condensers is prevented by back pressure valves, which also open in case excess pressure builds up in the receiver tank, and bypasses are arranged, so that any cooler, condenser or heater may be out of service, yet the system be kept in operation.

Arrangement of oil heaters in the plan is seen at the left in the section, Fig. 5 at the back of the boilers.

Boiler Equipment

As will be noted from the plan, the boilers are arranged on two sides of an aisle running longitudinally with the turbine room. The three boilers comprising the first installation have been erected on the turbine room side of this aisle. These are of the Babcock & Wilcox cross drum type, 24,450 sq. ft. of heating surface, with the firing front under the downtake header. Special circulating tubes shown in Fig. 5, running from the top of the uptake header into the boiler drum, have been provided to preclude the possibility of any steam binding in the top of the uptake header.

Oil burners are all of a special combination type, arranged for the burning of either oil or gas, Fig. 4. For access to the furnace the oil burner section of these burners can be swung back on hinges, leaving a clear 15-in. opening through the gas ring. Suitable doors have been provided in the side and rear walls for observation of the fire. Air for combustion is drawn through the air preheaters, which are of the tubular type, by a forced draft fan, carried thence down the side and rear walls and beneath the furnace hearth to the burner front. Control of

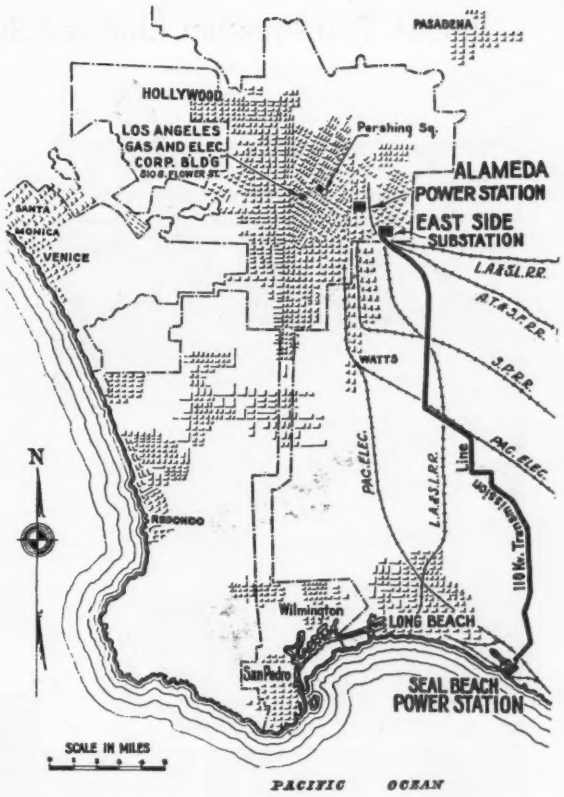


FIG. 1. SEAL BEACH ON THE OCEAN FRONT WITH 30-MI. TRANSMISSION LINE TO LOS ANGELES

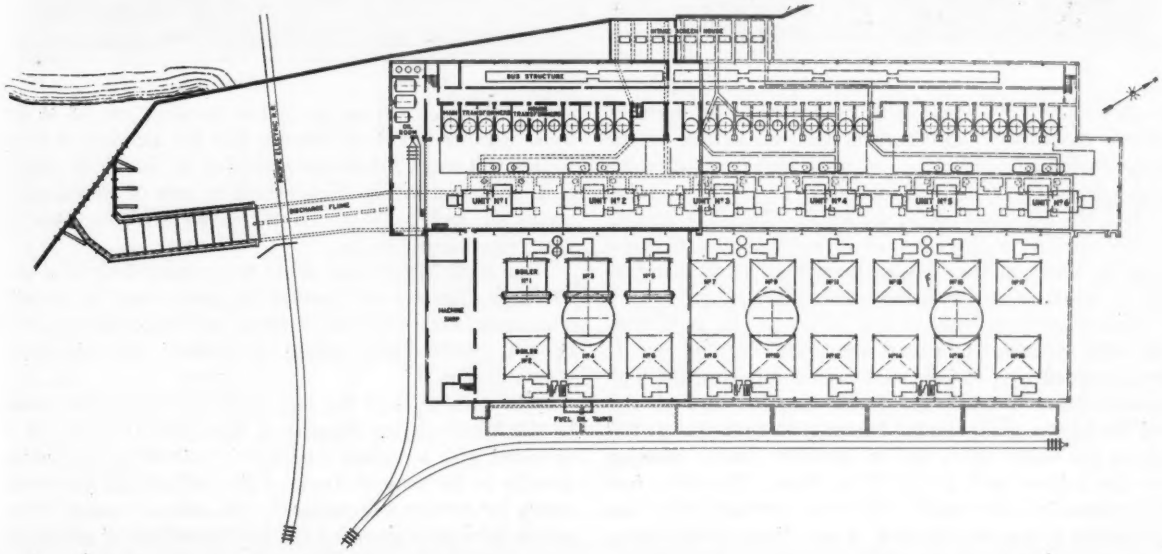
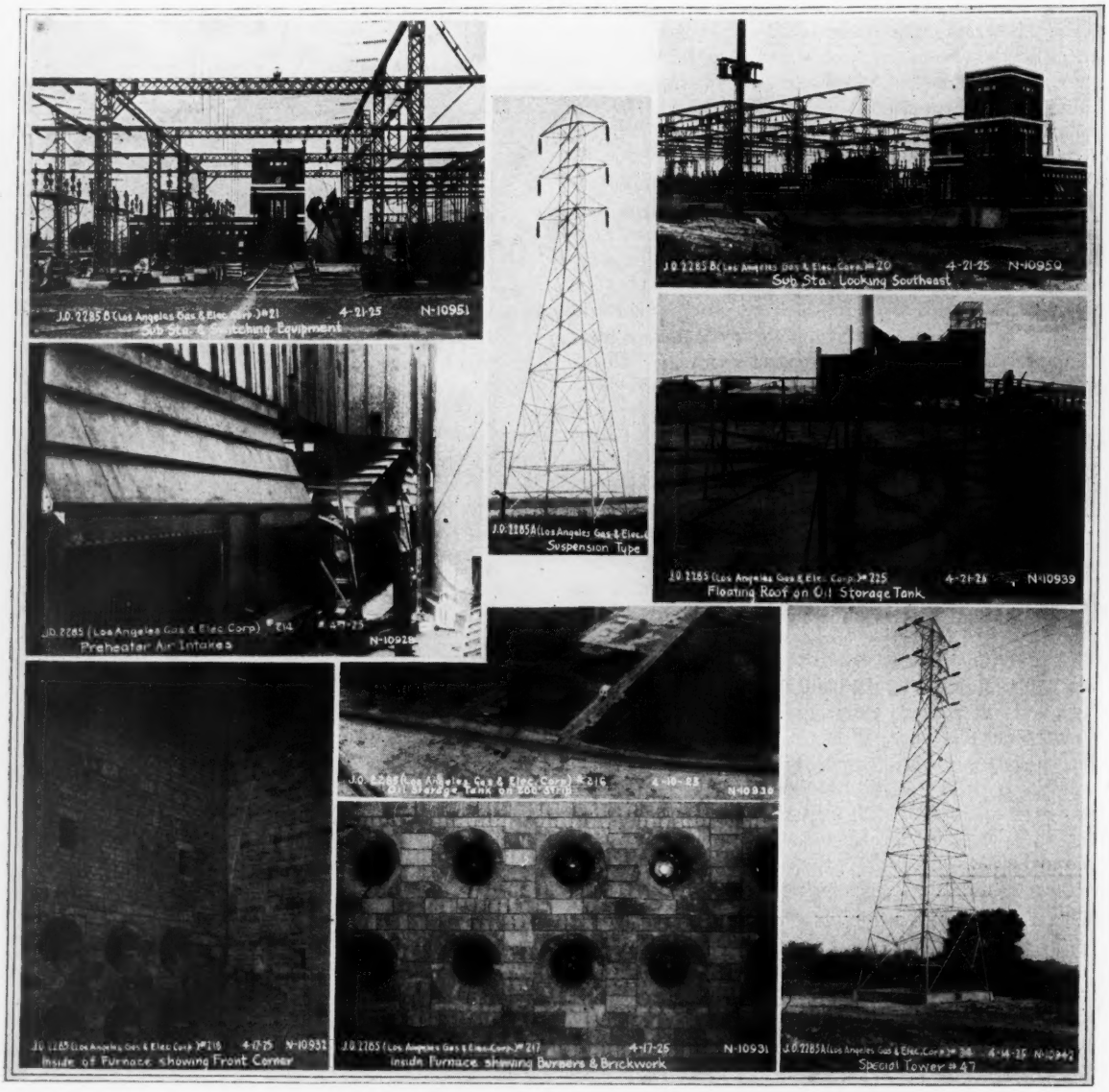


FIG. 2. PRESENT BUILDING TO HOUSE TWO UNITS, ONE INSTALLED. COMPLETE PLANT IS TO BE SIX UNITS

Boiler, Transmission Line and Substation Equipment at Seal Beach


Sub Sta. Looking Southeast
Suspension Type
Floating Roof on Oil Storage Tank
Preheater Air Intakes
Inside of Furnace showing Front Corner
Inside Furnace showing Burners & Brickwork
Special Tower #47

the air supply for combustion is accomplished by means of suitable dampers on the burners and regulation of the forced draft fan speed. The air preheater is placed in the uptake from the boiler, as shown in Fig. 5, with tubes carrying the flue gases placed vertically. The air is brought in and carried in three passes at right angles to these tubes, by which means it is expected that its temperature will be raised to approximately 300 deg. F.

Boilers are to operate at 375 lb. per sq. in. gage pressure, with superheat to a total temperature of 700 deg. F. Sargol welded type of joints are used throughout the high pressure steam system. The boilers are fed through two feed headers, a main header running beneath the central aisle of the boiler room, and an auxiliary header running over the boilers, each being 12 in. diam. The 6-in. feed connections from the main header are provided with Venturi meters to measure the flow to each boiler individually, but no metering arrangements have been provided for the auxiliary header as this is for use only in case of emergency. Blowdown from the boilers is taken care of in the usual manner but it is expected that the blowing of these boilers will be an infrequent operation as the water supply is entirely distilled so that, except in case of considerable condenser leakage, there should be no need for blowing down the boilers.

One stack 375 ft. high above the furnace floor level and 23 ft. in diameter will handle the gases from six boilers. This stack is of reinforced concrete, unlined, and supported upon a concrete mat resting on a heavy steel structure, shown in Fig. 5.

The turbine is of the new divided exhaust type made by the Westinghouse Electric & Manufacturing Co. It is provided with a surface condenser of 45,000 sq. ft., bolted directly to the exhaust flange of the turbine and supported partly by springs and partly by the turbine casing. Four points have been provided for the extraction of steam for heating the feed water. The steam conditions at these four points will be as follows:

First Bleeder, 3.67 lb. absolute, 95.1 per cent quality; second bleeder, 14.55 lb. absolute, 99.77 per cent quality; third bleeder, 58 lb. absolute, 109 deg. F. superheat; fourth bleeder, 170 lb. absolute, 208 deg. F. superheat.

Feed water leaves the last heater at a temperature of approximately 360 deg. F.

Figure 7 shows the flow diagram for the steam and condensate cycle with the quantities and temperatures prevailing at the different points therein. The evaporators supply the entire makeup for the station taking steam from the No. 3 bleed point, and passing the vapor and drainage into the No. 2 heater. These evaporators have a capacity at full load of 7500 lb. of water per hour each. Only one evaporator is required in this station per unit, but a second evaporator has been installed to provide spare capacity.

Condensate passes from the hot well pumps directly to the surface-type, generator-air coolers, located directly beneath the generators, see Fig. 6. These coolers consist of five sections through which condensate is passed, and three sections through which circulating water may be passed in case of failure of the condensate sections or other difficulty with the condensate part of the coolers. From the generator air cooler, the condensate passes through a pair of heat exchangers which cool the water for cooling the station transformers. In some steam plants, difficulty has been experienced due to fouling of the transformer cooling coils when raw water was used as a cooling medium and, in order to avoid this difficulty, the cooling system for the transformers contains only distilled water, which is recirculated through the coolers described above so that any likelihood of fouling of the transformer coils or piping is precluded.

From the heat exchangers the condensate passes through bearing oil coolers, thence to the inter and after coolers of the steam jet air ejectors. From this point it passes to the first heater. The entire system of cooling with condensate has for its main object avoidance of fouling and the consequent necessity for cleaning of the various pieces of cooling equipment in the station. Bearing oil coolers, heat exchangers and air ejectors are located on galleries beneath the turbine room floor, which may be clearly seen from the cross sections, Fig. 5 and view Fig. 8. Two motor driven hot well pumps are provided for each unit, either of which is large enough to carry the condensate away at full load.

Condensate outlet from the condenser is a 14-in. line; all other feed lines are 8-in. up to the feed water headers, which are 12-in., with 8-in. lines to bypass each piece of apparatus in the feed system.

The boiler feed pumps, which are six stage, have the driving motor located in the center, three stages being on each side of the motor. This construction is made advisable by the length of unsupported shaft that would be required, were the six stages placed in one casing and results in a more compact design than could be realized if a bearing were placed in the center of the pump with the motor at one end of the unit. One turbine driven boiler feed pump has been provided which will serve the entire station, for use in case of failure of the auxiliary power supply.

Under normal operation makeup water is evaporated

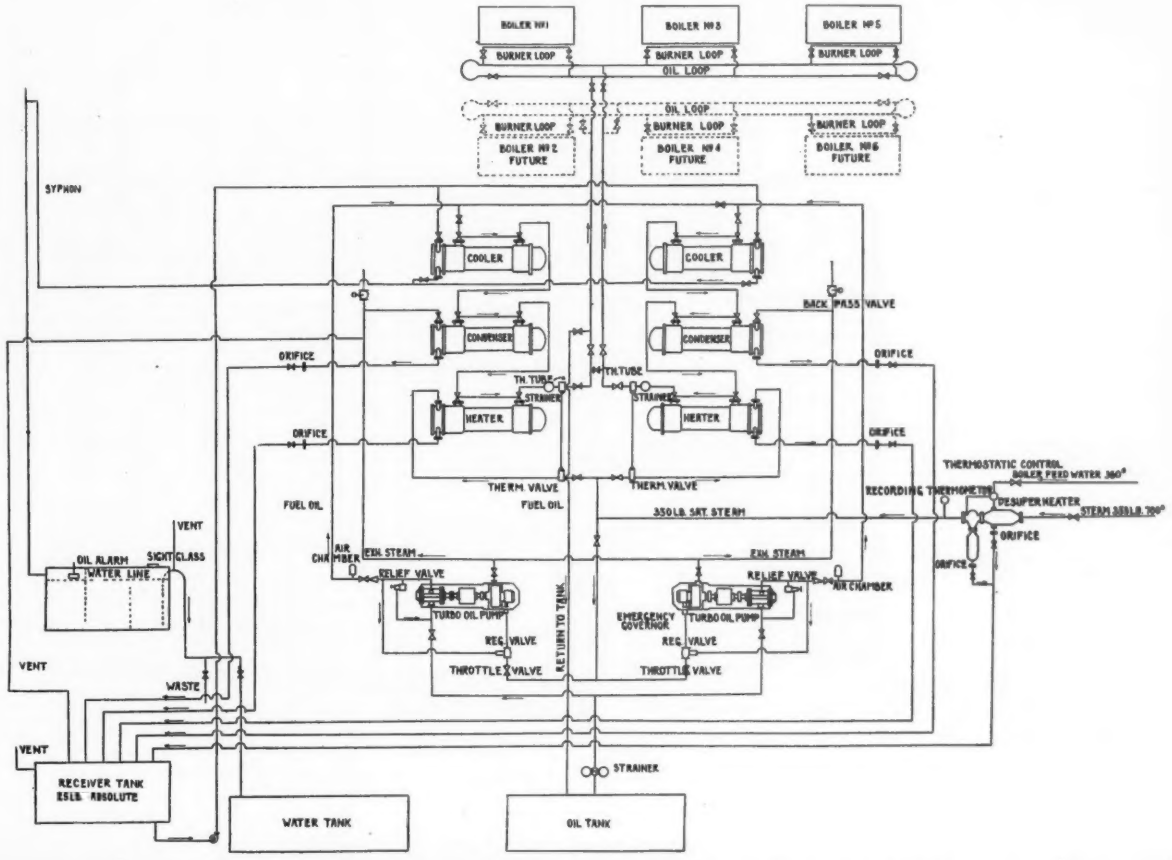


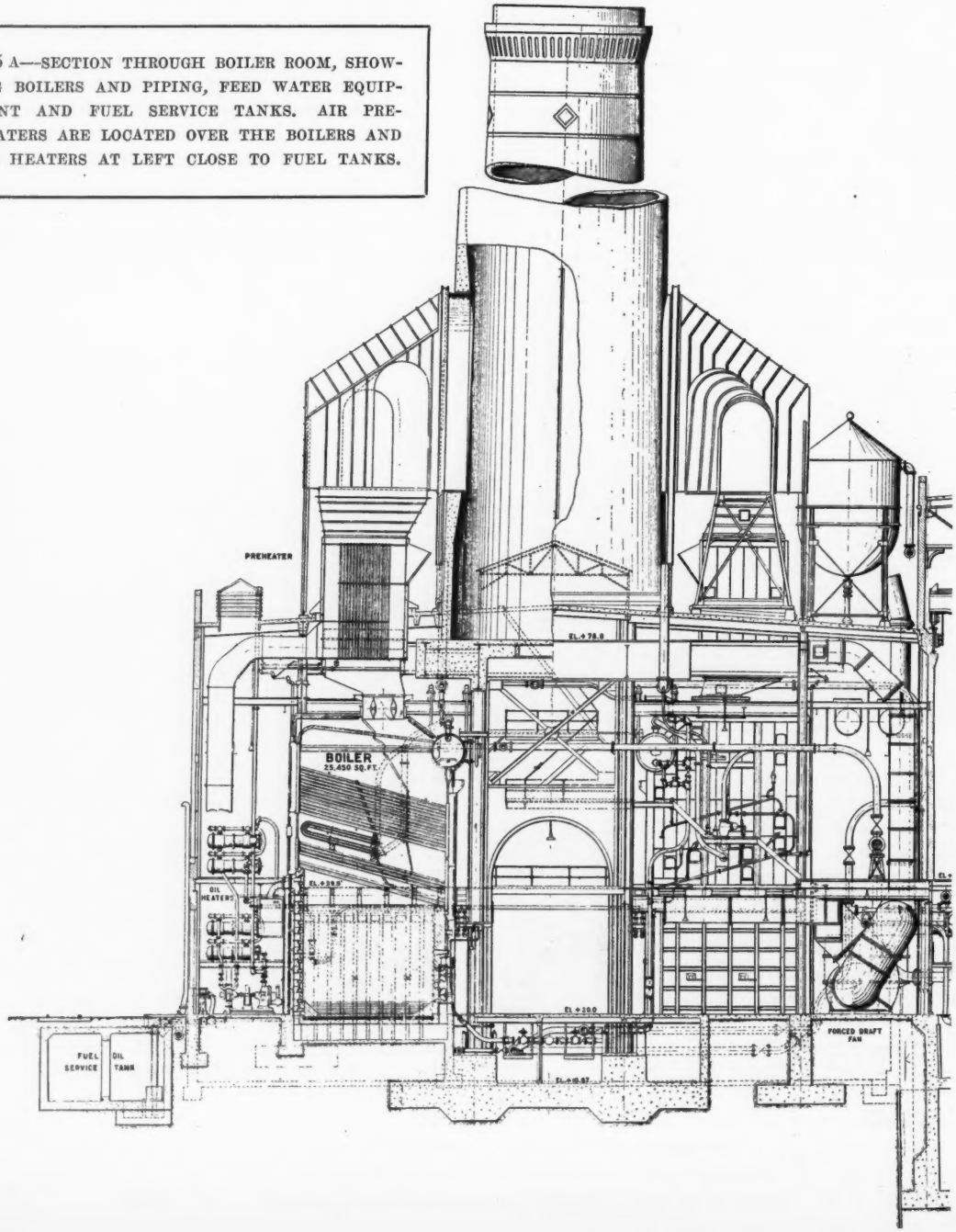
FIG. 3. FUEL OIL IS HEATED IN THREE STAGES AND FED TO A LOOP SYSTEM

and the vapor passes from the evaporator to No. 2 heater where it is condensed and passes with the drains into the steam space of No. 1 heater and is pumped into the condensate flow along with the drains from this heater.

Boiler feed pumps feed through Nos. 3 and 4 heaters to the main 12-in. boiler feed header from which 6-in. duplicate feed lines supply each boiler, the feed being controlled by Copes regulators. In extreme emergency, such as the failure of one of the heaters, the 8-in. bypass may be used.

Condensers are two-pass and have the water boxes divided vertically in such a manner that half of the condenser may be taken out of service for cleaning while the other half is in operation. Circulating water is taken from the bay side of the plant through traveling water screens and pumped to the condenser by motor driven pumps each having a capacity of 25,000 gal. per min. The discharge pipes from the condenser are sealed in the discharge tunnel so that a syphon is maintained at all times. The condenser cooling water is discharged on the ocean side of the plant, thus avoiding, as mentioned before, any tendency to recirculation. The ocean waters in this neighborhood contain great masses of semi-floating kelp which have caused considerable trouble in some of the plants which have been built to take water directly from the ocean. In selecting the site for this plant this feature was

FIG. 5 A—SECTION THROUGH BOILER ROOM, SHOWING BOILERS AND PIPING, FEED WATER EQUIPMENT AND FUEL SERVICE TANKS. AIR PREHEATERS ARE LOCATED OVER THE BOILERS AND OIL HEATERS AT LEFT CLOSE TO FUEL TANKS.



given due consideration and a location on a bay or inlet was sought, of such a nature that this drifting kelp would not be drawn into the intake.

Electrical System

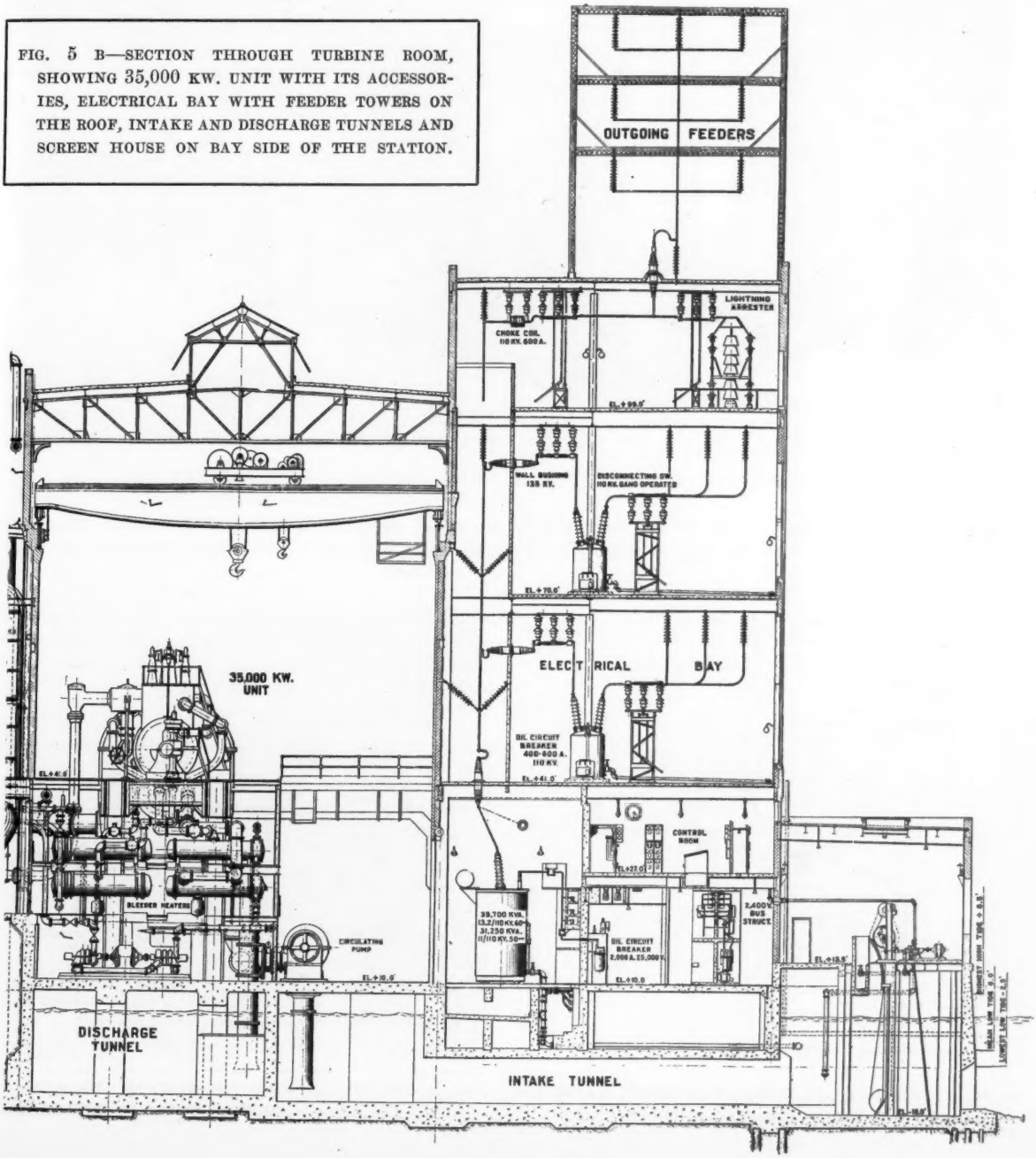
Electrical circuits in the station were arranged with a view to reliability and simplicity. Main 13,200-v. generators, Fig. 9, are connected directly to their respective step-up transformers which in turn connect to either of the 110-kv. main station buses, thereby eliminating all heavy duty 13,200-v. switching. It is intended that, ultimately, there shall be no switch between the generator and its transformers, although one has been installed in this first unit for synchronizing only. Subsequent units will be so equipped only in case experience indicates the necessity for such installation.

In Fig. 10 is shown the main line diagram of the system for units Nos. 1 and 2 and connections to the East Side substation. Connections for the other units will be the same but, eventually, another substation will be added to supply outgoing feeders Nos. 8 to 14 and the two substations will be interconnected, the switches for this being shown dotted at the right hand end of the 110-kv. substation buses.

Each single phase transformer is located in an individual fireproof compartment, separated from the turbine room by a rolling steel door, rails being provided in each compartment so that a transformer may be rolled into the turbine room and picked up by the turbine room crane.

Beneath each transformer is a concrete pit, large enough to hold the entire oil content of the transformer,

FIG. 5 B—SECTION THROUGH TURBINE ROOM, SHOWING 35,000 KW. UNIT WITH ITS ACCESSORIES, ELECTRICAL BAY WITH FEEDER TOWERS ON THE ROOF, INTAKE AND DISCHARGE TUNNELS AND SCREEN HOUSE ON BAY SIDE OF THE STATION.



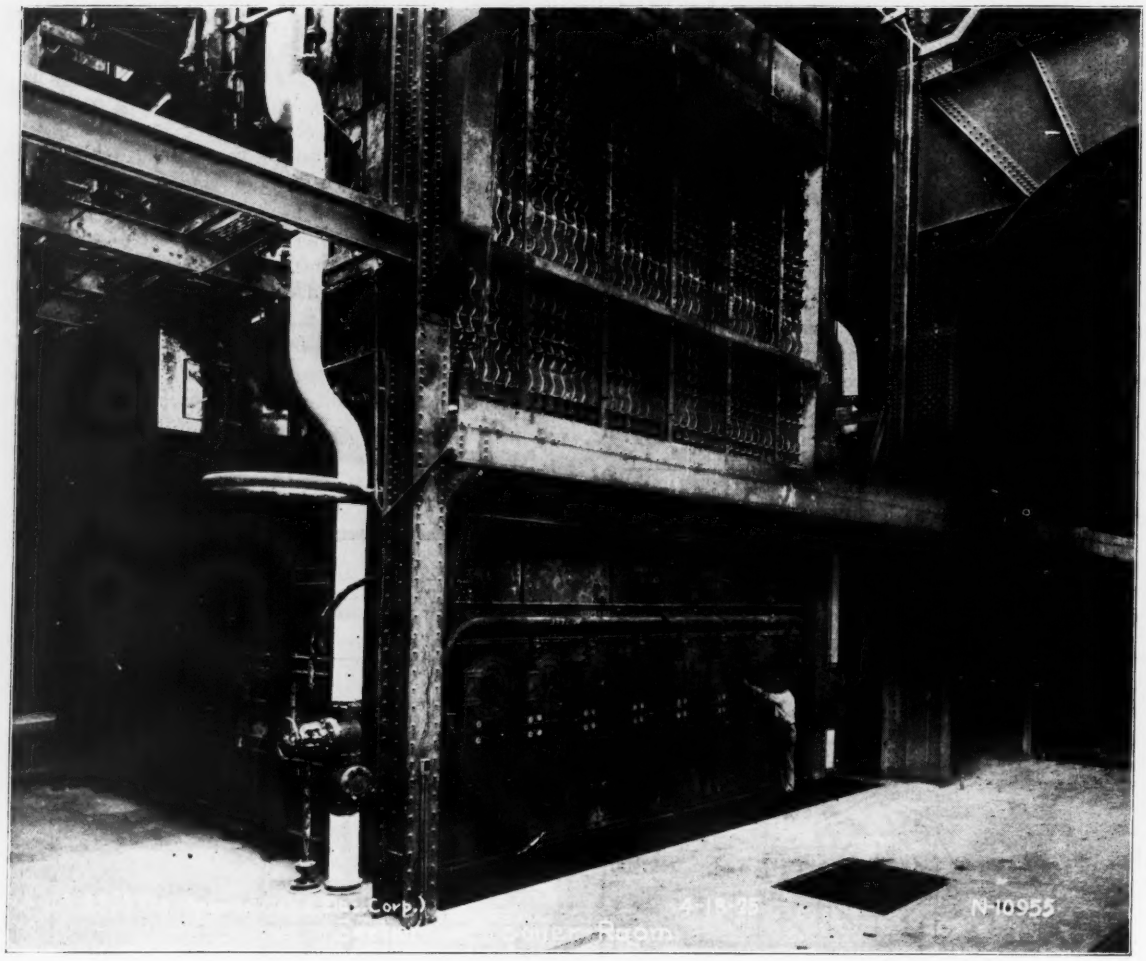


FIG. 4. BOILERS HAVE OIL AND GAS BURNERS. HEAVY STEEL ARCHES SUPPORT THE STACKS

drained to an emergency tank outside the building. Quick opening valves, controlled from the turbine room, provide for rapid disposal of oil in case of fire and remote controlled CO_2 equipment is installed to smother a fire in any compartment.

The two main 110-kv. buses are housed on the upper floors of the electrical bay rather than outdoors to preclude possibility of trouble from salt fogs from the sea at this location. Connections from the main transformers to the buses are isolated in vertical wells.

Inside the station the course of current from the main

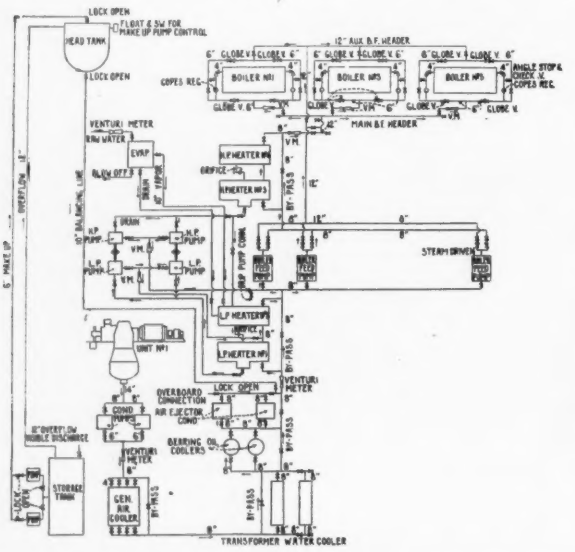


FIG. 6. CONDENSATE AND DISTILLED MAKE-UP WATER ARE HEATED BY BLEEDING FROM INTERMEDIATE STAGES

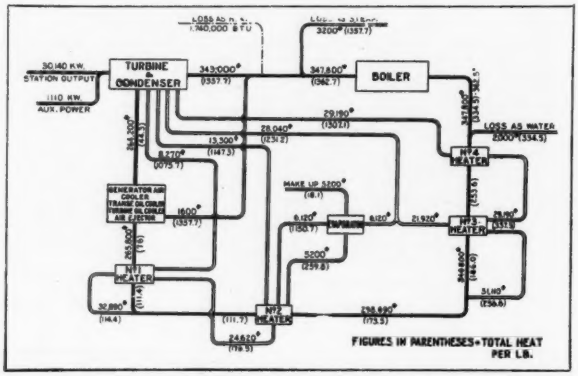


FIG. 7. POUNDS OF STEAM PER TURBINE AND HEAT PER POUND ARE SHOWN FOR EACH POINT IN THE SYSTEM

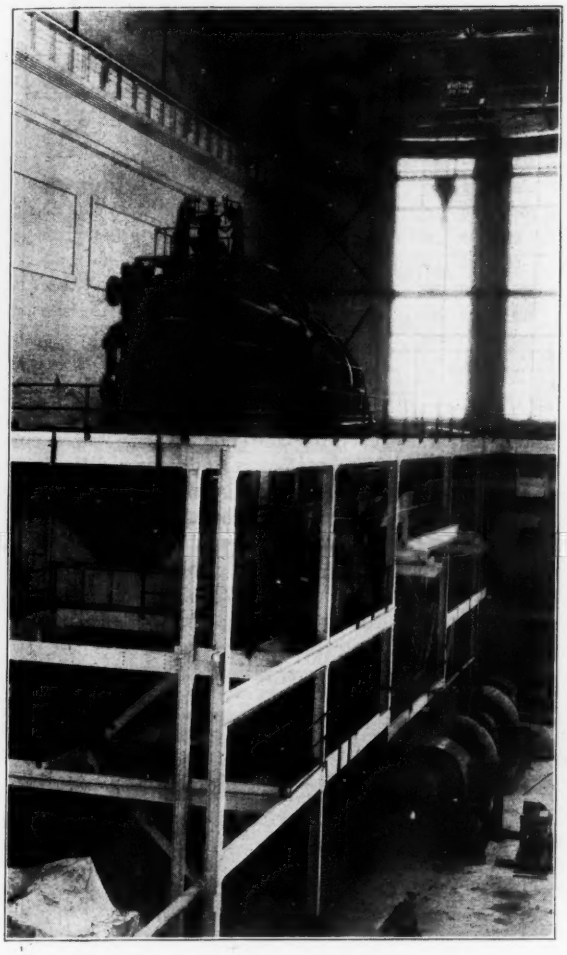


FIG. 8. BELOW THE TURBINE ARE THE CONDENSER AND CONDENSATE PUMPS. OIL COOLERS AND HEAT EXCHANGERS ARE LOCATED ON GALLERIES

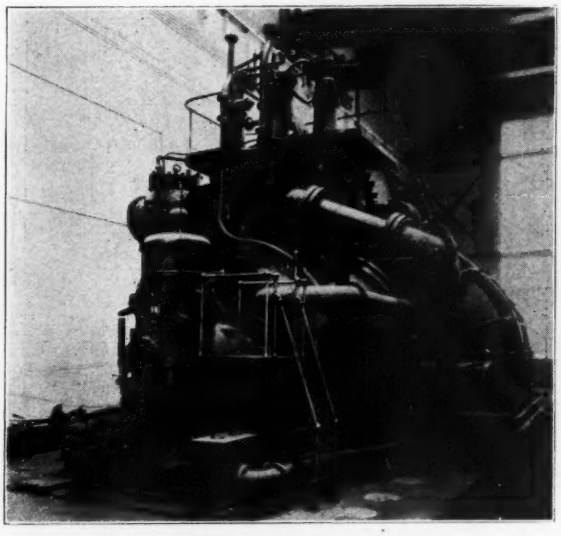


FIG. 9. MAIN AND AUXILIARY GENERATORS ARE DRIVEN BY THE SAME TURBINE

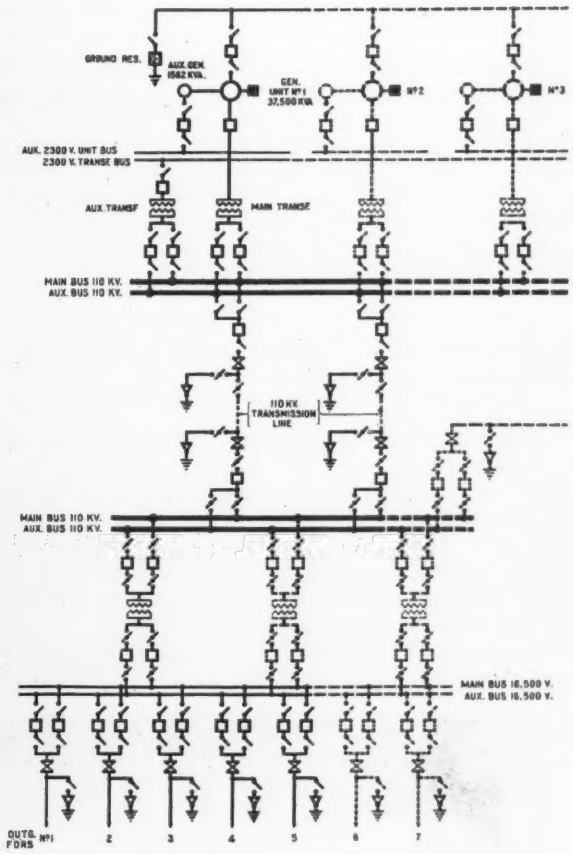


FIG. 10. GENERAL ARRANGEMENT OF THE ELECTRIC SYSTEM AND PRINCIPAL APPARATUS IS HERE SHOWN

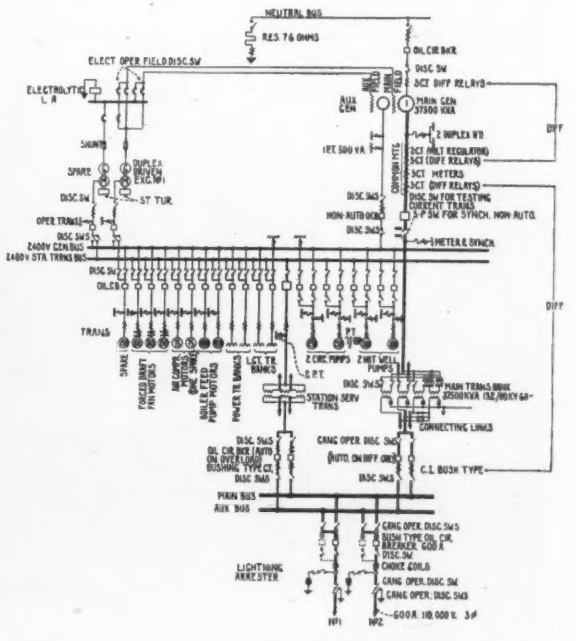


FIG. 11. GENERATOR, TRANSFORMER, BUS AND MOTOR CONNECTIONS

STATION AUXILIARIES AND DRIVE

	Boiler Room					Generators				Station Service							
	Present 3 blrs.		Ultimate 18 blrs.			1 unit prog.		6 unit ult.		440 v. system & lights (100-300 total)							
Motors	Forced Draft	Spare	Blr. Feed	Air Comp.	Total A	Circ. Pump	H. W. Pump	Exciter	Total B	Serv.	Crane Elev.	Screen	Trans. Cooling	Stor-age	Misc.	Total C	Total A+B+C
					hp.				hp.							hp.	hp.
Present	3	2	2	1	hp.	2	2	2		2		2	2	1	--		
Ultimate	18		7	1	- .	12	12	7	--	12		12	12	2	--		
Size	150 hp.	150 hp. 100 hp.	400 hp.	75 hp.		250 hp.	100 hp.	310 hp.	--	50 hp.	291 hp.**	7.5 hp.	40 hp.	65 hp.	--		
1-Unit Normal	200		350	65	615	360	70	300	730	60	--	7.5	40	40	55	202.5	1547.5
1-Unit Emerg.	200		350	0	550	360	70	300	730	0	--	7.	40	0	25	72.5	1352.5
1-Unit cold starting	0		150	0	150	180	50	0*	230	0	--	0	20	0	0	20	400
1-Unit warm starting	0		0	0	0	180	50	0*	230	0	--	0	20	0	0	20	250
Ultim. Normal	1200		2100	65	3365	2160	420	1800	4380	360	--	45	240	80	190	915	8660
Conn. Load-1 unit	450		800	75	1325	500	200	620	1320	100	291	15	80	65	162	713	3358
" " -Ultim.	2700		2800	75	5575	3000	1200	2170	6370	600	291	90	480	130	535	2126	14071

* Note:- Assumed steam is available under this condition

**Trav. Crane--Hoist 1-100; Bridge 1-83; Trolley 1-25; Aux. 1-83

generators is as follows, see Fig. 11: The main, 37,500-kv.a., 13,200-v., and auxiliary, 1562-kv.a., 2400-v., generators are driven by one main turbine, field excitation for both being taken from an exciter bus, which in turn is supplied by 200-kw., 250-v., duplex-driven exciters. At these voltages the current is 3-phase at 60 cycles. If speed be reduced to give 50-cycles, the e.m.f.'s will be 11,000-v. and 2000-v. respectively.

The neutral of the main generator is connected to a neutral bus, which in turn is grounded. This connection includes, between generator and neutral bus, three current transformers, 2000 to 5-amp., operating differential relays; a single-pole 600-amp. disconnecting switch; a single-pole oil circuit breaker of like capacity; a 600 to 6-amp. current transformer and a second single-pole disconnect switch. Between the neutral bus and ground is a like disconnect switch; a resistance of 7.6-ohms to carry 1000-amp. for 2 min. and a 600 to 5-amp. current transformer.

In the main circuit from the generator are first, two duplex potential transformers, ratio 13,200 to 110-v.; next,

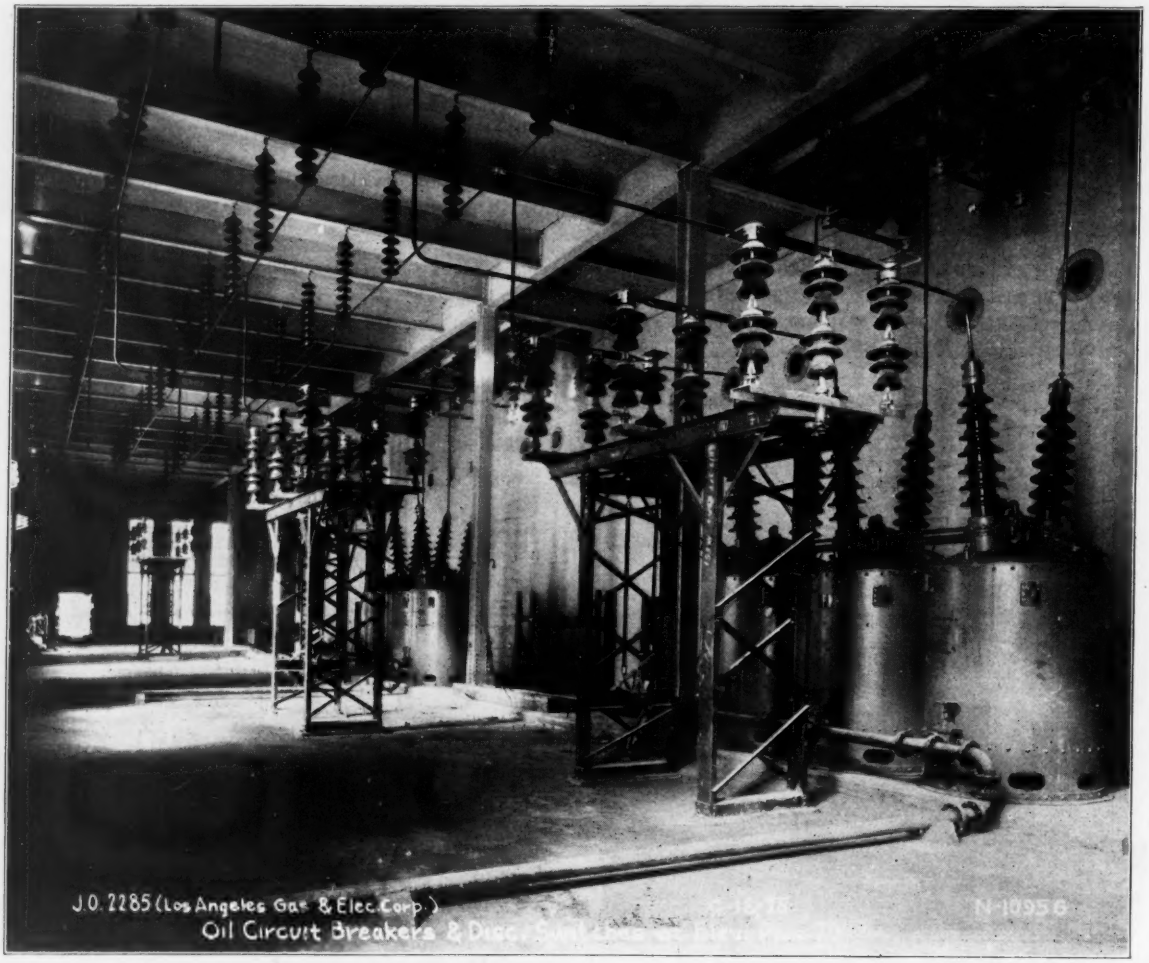


FIG. 12. DISCONNECTING SWITCHES AND CIRCUIT BREAKERS ARE PLACED IN GALLERIES IN THE ELECTRICAL BAY

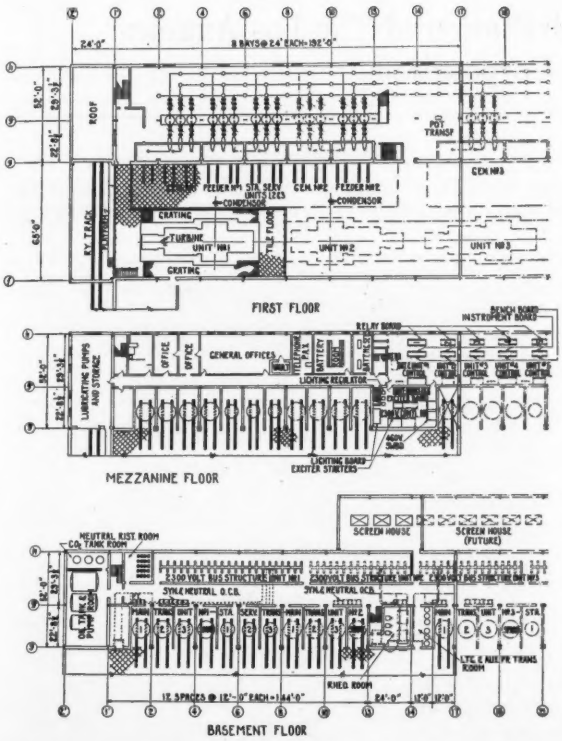


FIG. 13. THESE PLANS, IN CONNECTION WITH FIG. 5, SHOW THE ARRANGEMENT OF EQUIPMENT AT VARIOUS LEVELS

on a common mounting, two current transformers for the voltage regulation and differential relay control, tied in with those on the neutral bus, three for meters and another three for differential relays. All are 2000 to 5-amp. ratio.

Connection to the step-up transformers, which are single-phase with ratio 13,200 to 110,000-v. and bank capacity of 37,500-kv.a. is by 12 single-pole, 2000-amp., single-throw switches. Six of these are used for connecting the regular transformers. The fourth transformer, a spare, has six switches so that it may be thrown into any one of the phases as required.

One side of each transformer high-tension winding is connected to a common lead to ground, thus forming a neutral point. The other sides are carried to the transmission line, the spare transformer having connecting links so that it may be thrown on any phase, according to the primary connections which are being used.

High-tension transformer connections are in duplicate from the transformers to duplicate buses and have two sets of gang disconnecting switches; oil circuit breakers, which

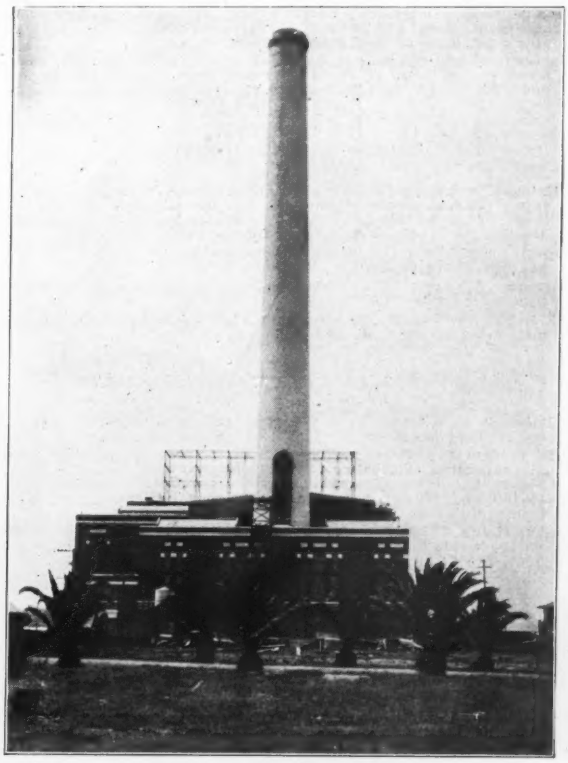


FIG. 15. PRESENT DEVELOPMENT OF SEAL BEACH STATION

are automatic only on action of the differential relays from the generator mains; and current transformers connecting to these differential relays. All switches are for 110,000 v.

In the connections to outgoing lines from the duplicate high-tension buses are disconnect switches and, in each transmission line, an oil circuit breaker with disconnecting switches. Beyond these is a choke-coil followed by a lightning arrester, which can be cut out by a disconnect switch, and a final line gang disconnect with an auxiliary switch by means of which the line may be grounded.

For station load, two 2400-v buses are provided, one supplied from the auxiliary generator, the other from a step-down transformer, of 6000 kv.a. capacity taking current from either of the main 110,000-v. buses. Between each main bus and the service transformer is a gang disconnecting switch, an oil circuit breaker automatic on overload, and a second gang disconnect; also 80 to 5-amp. current transformers on each side of the circuit breaker. Between the service transformer and the auxiliary bus are two potential transformers, 2400—120-v., three current transformers, 2000 to 5-amp., and a 2000-amp. oil circuit breaker, electrically operated.

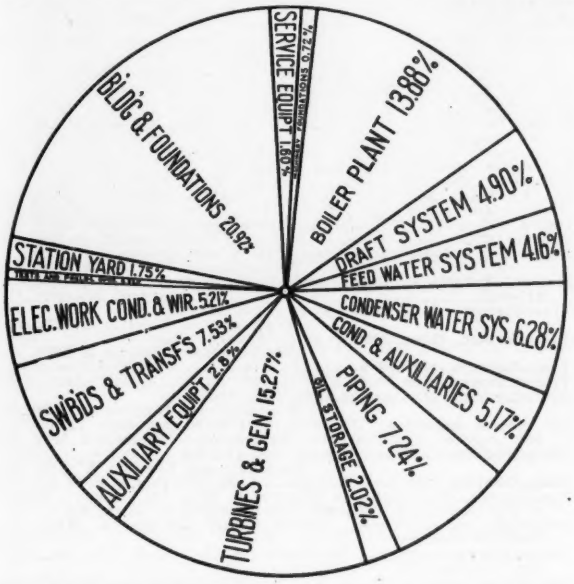


FIG. 14. COST FOR THE STATION IS HERE SHOWN DIVIDED INTO PERCENTAGES FOR THE VARIOUS PARTS

Principal Equipment of Seal Beach Station of The Los Angeles Gas and Electric Corporation

General

Location of plant, on Pacific Ocean at Seal Beach, California.

Capacity of present building, 70,000 kw.; ultimate capacity, 200,000 kw.

Boiler Room dimensions, 115 ft. 8 in. by 151 ft. 7 in.

Machine Shop and Storeroom, 115 ft. 8 in. by 33 ft. 8 in.

Height, boiler room floor to roof girders, 63 ft.

Width of firing aisle, 23 ft. 6 in.

Turbine room dimensions, 65 ft. by 217 ft. 10 in. Height from basement floor to turbine operating floor, 31 ft.; turbine operating floor to roof girders, 58 ft. 6 in.

Electric Gallery dimensions, 53 ft. by 217 ft. 10 in. Height, basement to 1st floor, 17 ft.; 1st to 2nd floor, 14 ft.; 2nd to 3rd floor, 29 ft.; 3rd to 4th floor, 29 ft.; 4th floor to roof girders, 20 ft.

Boilers and Superheaters

3 Babcock & Wilcox Co., cross-drum, vertically baffled boilers for three passes. Steam drum, 60 in. diam. by 32 ft. 9¼ in. long. 860 4-in. tubes, 24 ft. long. Water heating surface, 25,450 sq. ft. Working pressure, 385 lb. gage.

Superheat, 257 deg. F. Steam temperature, 700 deg. F. Superheaters, Babcock & Wilcox Co.

Furnace volume, 10,375 cu. ft.; volume per 10 sq. ft. of boiler heating surface, 4.06 cu. ft.

Oil Burners, Peabody Engineering Corp.; combination oil and gas with mechanical atomization.

Air Preheaters and Draft Equipment

3 Babcock & Wilcox Co. preheaters, tubular three-pass; 23,025 sq. ft. heating surface.

3 B. F. Sturtevant Co. horizontal, turbo-vane, ¾ housing fans; air capacity, 100,000 cu. ft. per min. at 200 deg. F.; speed, 660 r.p.m.; drive, General Electric Co. motors, induction type, 25-150 hp., 440-v.; motor control, General Electric Co., BTA, brush shifting.

Stack, Heine Chimney Co., concrete superimposed on steel supports; inside diameter at top, 23 ft.; height above boiler room floor, 375 ft.; above steel supports, 317 ft.

Boiler Feed Pumps and Water System

3 Worthington Pump & Machinery Corp., 1000 gal. per min.; 1 steam-driven, horizontal, double-suction, 4-stage, driven by 375-hp., single-stage non-condensing turbine at 2000 r.p.m.; 2 motor-driven, horizontal, double suction, 6-stage, driven by 400-hp., 3-phase, 60-50 cycle, 440-v., wound rotor, induction motors at 1800 r.p.m. Regulation by Ruggles-Klingemann excess pressure governors.

4 Griscom-Russell Co., horizontal, water-tube, closed type feedwater heaters with floating head.

2 Wheeler Condenser & Engineering Co., single-effect, vertical, submerged type evaporators; capacity 7500 lb. an hr.

Service Pumps

Fresh water service; 2 De Laval Steam Turbine Co., double-suction, single-stage pumps; capacity, 375 gal. per min.; drive, 20-hp. motors at 1800 r.p.m.

Salt water service; 2 De Laval, double-suction, single-stage pumps; capacity 750 gal. per min.; drive, 40-hp. motors at 1800 r.p.m.

Distilled water make-up; 2 De Laval, double-suction, single-stage pumps; capacity, 500 gal. per min.; drive, 25-hp. motors at 1800 r.p.m.

Transformer cooling-water service; 2 De Laval, double-suction, single-stage pumps; capacity, 300 gal. per min.; drive, 25-hp. motors at 1800 r.p.m.

All motors are of induction type, wound rotors, 3-phase, 50-60 cycle, 440-volt.

Fuel Oil System

Storage tanks, Chicago Bridge & Iron Works, steel with floating-deck roof; capacity 55,000 bbl.

Transfer pumps, 2 Byron Jackson Pump Mfg. Co., double-suction, single-stage; capacity, 350 gal. per min.; drive, 25-hp., wound-rotor induction motor at 1800 r.p.m.

Fuel oil feed pumps, 2 Kinney Mfg. Co., rotary; capacity, 115 gal. per min.; drive, General Electric turbine and reduction gear.

Oil heaters, C. F. Braun Co., counter-current, floating head, straight tube; 4-2 ft. 9⅝ in. by 8 ft. 10¾ in., capacity, 54,000 lb. an hr.; 8-2 ft. 5 in. by 8 ft. 5¾ in., capacity, 54,000 lb. an hr.

Oil filters, C. F. Braun Co.; 1—8-in. duplex; 2—4-in. duplex.

Turbo-Generator

1 unit installed. Westinghouse Electric & Mfg. Co., parallel flow.

Blading, 2 rows impulse, 19 rows reaction, 6 rows Bauman. Steam pressure, 350 lb. gage at throttle; superheat, 264 deg. F. at throttle.

Generator, 3-phase, 60-cycle, 13,200-v., 37,500-kv.a., 30,000-kw. at 80 per cent power factor, 1800 r.p.m.

Guaranteed water rate for 350 lb. gage pressure, 264 deg. superheat, 29 in. vacuum, no steam bled;

At 15,000 kw., 10.23 lb. steam per kw-hr.
At 22,500 kw., 9.62 lb. steam per kw-hr.
At 26,250 kw., 9.44 lb. steam per kw-hr.
At 30,000 kw., 9.49 lb. steam per kw-hr.
At 31,250 kw., 9.50 lb. steam per kw-hr.

Generator air cooler, Griscom-Russell Co., surface cooler for direct cooling of air without contact with water; condensate cooler, 26,300 sq. ft.; raw water cooler, 5781 sq. ft.

Condenser and Auxiliaries

1 Condenser, Wheeler Condenser & Engineering Co., surface, two-pass, horizontal; 45,000 sq. ft. cooling surface; 300,000 lb. steam an hr.

2 Circulating pumps per condenser; capacity of each, 25,000 g.p.m.; drive, 250-hp. induction motor at 2200 v.

2 Vacuum pumps per condenser; steam jet, two-stage type, with surface inter coolers and after condenser.

2 Hot-well pumps per condenser; 6-in., two-stage, centrifugal; drive, 100-hp. motor at 2200 v.

2 Link-Belt Co., traveling, self-cleaning screens; capacity, 35,000 g.p.m.; drive 5-hp. motor at 2200 v.

Exciters, 2 Westinghouse Electric & Mfg. Co., 200-kw.; drive, dual by either 310-hp. Westinghouse turbine or 310-hp. 3-phase, 2200 v. motor at 1200 r.p.m.

Turbine Room Crane, Whiting Corp., 100-t., 4-motor.

Miscellaneous Mechanical Equipment

Oiling system filter, batch and bypass arrangement ..... S. F. Bowser & Co., Inc.
Gate valves ..... Chapman Valve & Mfg. Co.
High-pressure Sargol piping ..... Crane Co.
Stop and check valves ..... Edward Valve & Mfg. Co.
Blow-off valves ..... Everlasting & Yarnall-Waring
Safety valves ..... Consolidated Safety Valve Co.
Water columns ..... Babcock & Wilcox Co.
Feed water regulators Copes ..... Northern Equipment Co.
Boiler feed pump governers ..... Ruggles-Klingemann Mfg. Co.
Atmospheric relief valves ..... Atwood & Morrill Co.
Structural steel ..... Llewellyn Iron Works
Steel sash and ventilators ... Fenestra, Detroit Steel Products Co.
Skylights ..... Fred W. Dee
Rolling doors ..... J. G. Wilson Co.
Metal doors ..... National Cornice Works
Floor gratings ..... Arrowhead Iron Works

Station Instruments

Venturi meters ..... Simplex Valve & Meter Co.
Steam meters ..... General Electric Co.
Gas meters ..... Republic Flow Meters Co.
Recording thermometers and gages ..... Foxboro Co.
Indicating thermometers ..... C. J. Tagliabue Mfg. Co.
CO_2 Recorder, Mono ..... C. J. Tagliabue Mfg. Co.
Draft gages ..... Bailey Meter Co.
Indicating gages ..... Ashton Valve Co. and Ashcroft Mfg. Co.
Concentration meters ..... Esterline-Angus Co.
Bench board, instruments and station aux. board ..... Westinghouse Electric & Mfg. Co.
Motors, induction, 75-hp. and over, 2300-volt; under 75-hp., 440-volt ..... General Electric Co.
Transformers, four 12,500 kv.a. 13,200/110,000-volt ..... Westinghouse Electric & Mfg. Co.
Transformer, three 2000-kv.a. 110,000/2300-volt ..... Westinghouse Electric & Mfg. Co.
Transformers, six 200-kv.a. 2300/440-volt .... General Electric Co.
Transformers, nine 50-kv.a. 2300/440-volt .... General Electric Co.
Transformers, six 50-kv.a. 2300/220/110-volt ..... Westinghouse Electric & Mfg. Co.
Oil circuit breakers, 110,000-volt, 400-600 ampere; 13,200-volt 200 ampere; motor circuits. Westinghouse Electric & Mfg. Co.
Disconnecting switches, 110-kv. and 13.2 kv. ..... Westinghouse Electric & Mfg. Co.
Disconnecting switches, 7500-kv. .... Electric Power & Equip. Co.
Insulators ... Westinghouse Electric & Mfg. Co., Electric Power & Equipment Co., Electric Development & Mach. Co.
Potential transformers ... Westinghouse Electric & Mfg. Co., General Electric Co.
Current transformers ... Westinghouse Electric & Mfg. Co., General Electric Co.
Storage battery ..... Electric Storage Battery Co.
Storage battery charging set .. Westinghouse Electric & Mfg. Co.
Transmission Line Towers ..... Pacific Coast Steel Co.

In the line from the auxiliary generator to its bus are three potential transformers 2400—120-v.; a 600-amp., oil circuit breaker, non-automatic, with 600-amp. disconnecting switches on either side; and two 500—5-amp. current transformers.

From either auxiliary bus connections run to the station motors, shown in the table, and to two banks of step-down transformers, one having two 500-kv.a., 2300-460 v. transformers for power, the other two 150-kv.a. 2300-230 and 115 v. transformers for lighting. Each circuit has switches for connection to either bus, also a 600-amp., automotive oil circuit breaker, a potential transformer and two current transformers of proper capacity for the circuits. Air compressor motors and pump motors use 2300 v. direct. Forced draft fan motors have transformers stepping down from 2300 to 460-v.

Duplicate circuit breakers on the circulating and hot-well pump lines are mechanically interlocked.

Exciter motors are protected by oil circuit breakers and by carbon breakers, in lines to bus and to fields. A discharge arrester is provided on the exciter bus to protect the generator field circuits against inductive surges in case of an exciter breaker opening accidentally.

Arrangement of the electrical bay is shown at the right in Fig. 5, and a few of the oil circuit breakers and disconnecting switches in Fig. 12.

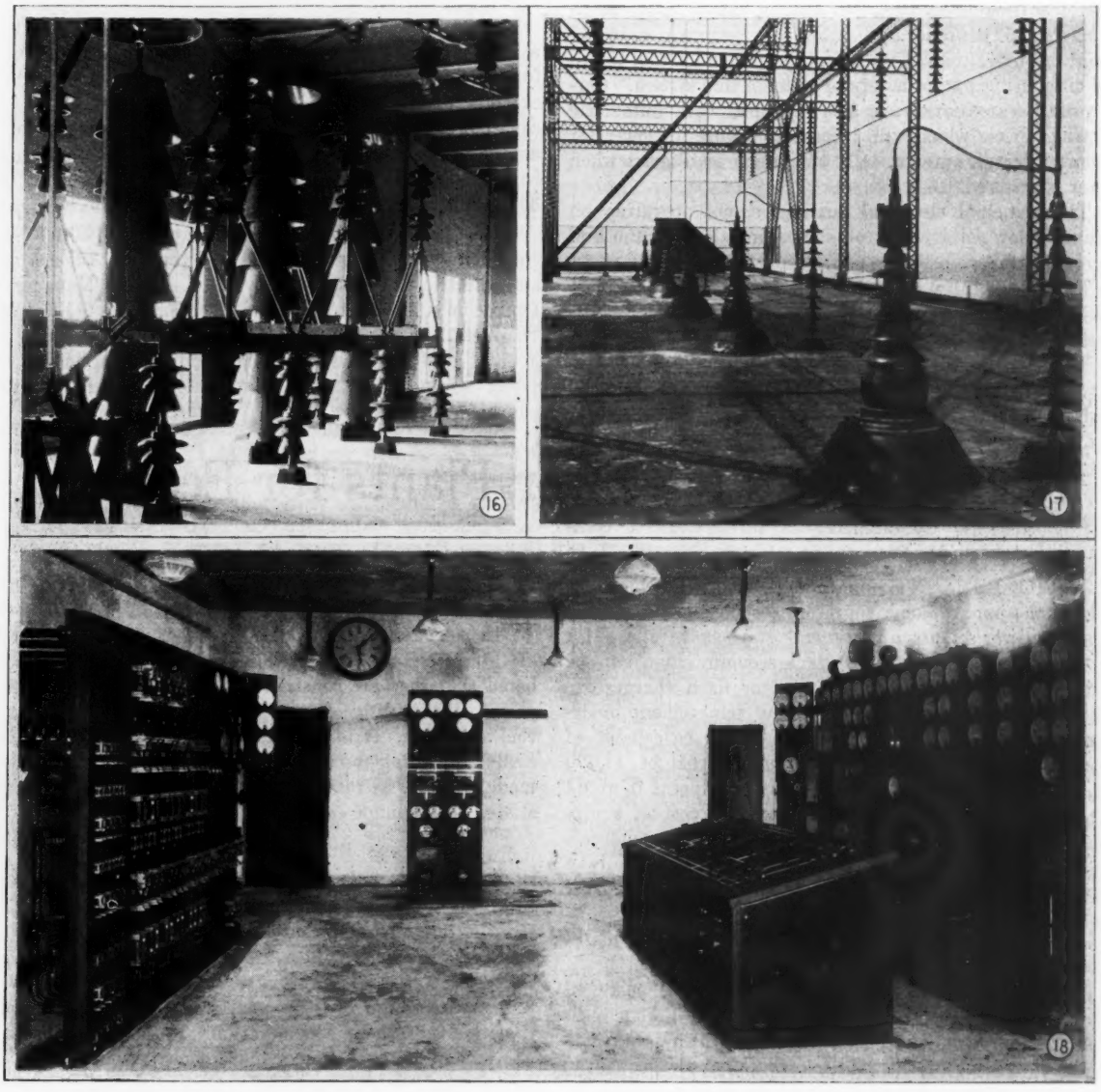


FIG. 16. THESE LIGHTNING ARRESTERS PROTECT THE STATION. FIG. 17. CURRENT PASSES TO THE ROOF TAKE OFF THROUGH THESE TERMINALS AT 110,000 V. FIG. 18. BOARD AT THE LEFT CONTROLS THE STORAGE BATTERY; EXCITER BOARD CENTER; MAIN SWITCHBOARD AT THE RIGHT

Two 3-phase transmission circuits leave the electrical bay from a structure on the roof, and are carried on a steel tower line northerly toward Los Angeles, terminating at the new East Side substation, located in the southeastern section of the City of Los Angeles.

Electric power for station auxiliaries may be taken, as

stated previously either from the main station bus, through the station service transformers, or from the auxiliary generator, separate buses being provided for the auxiliary generator and the station service transformers. The switching arrangement is so designed that, in case of failure of power on one bus, certain apparatus will be automatically thrown over to the other, so that, unless the power supply on both buses fails, no interruption to vital auxiliary operation results. This system of automatic motor control will cause a motor, in case of low voltage, to be transferred to the other bus. A lock-out feature is provided to prevent more than three operations. The hot-well pump and circulating pump motors operate on this system. Certain of the auxiliaries are also equipped with automatic starting devices which will, in case of failure of power for a short interval, automatically start such auxiliaries when power is restored.

The principal electrical auxiliaries, not operating on automatic low voltage control, as now installed for the first generator are:

Two electrically driven boiler feed pumps equipped with automatic speed control operating on changes of difference between feed line and boiler pressures.

Two duplex drive exciters driven normally by motor, but with turbine drive provided automatically to pick up load on a 3 per cent drop in motor speed.

Three forced draft fans in the boiler room driven by variable speed brush shifting motors.

Although various station auxiliaries require a variable-speed drive, the necessity of a source of direct-current power, with its converting equipment, has been eliminated by the use of variable-speed alternating-current motor equipment.

Complete telephone, load-indicating and emergency lighting systems are installed.

Investment cost for the completed two-unit station, using the same unit prices for the second unit as obtained for the first, will be $85 per kilowatt, based on the actual capacity of the machines, namely, 35,000-kw. at 80 per cent power factor. While the machine was bought for a nominal rating of 30,000-kw., tests have shown that it can be conservatively rated at 35,000-kw. The cost, using the 30,000-kw. rating, is $100 per kilowatt.

This project has been directed by A. B. Day, Vice President and General Manager of the Los Angeles Gas and Electric Corp., assisted by H. J. Kister, Manager of Operation and Construction, and J. G. Rollow, Electrical Engineer. Dwight P. Robinson & Co., Inc., acting as agents, have executed the design and construction of the power station, the transmission lines and the substation connected therewith.

Design of Steam Power Plants for Economy

BUSINESS CONSIDERATIONS GOVERN TO A GREAT EXTENT THE INCREASED CAPITAL AND FIXED CHARGES ACCOMPANYING HIGHER EFFICIENCY AND GREATER FUEL ECONOMY. BY JAMES A. POWELL*

AT THE PRESENT time there seems to be a tendency on the part of some engineers responsible for the design of power plants and central stations to strive for higher efficiency and greater fuel economy than can be justified when the increased capital or fixed charges are considered. It would be a noteworthy achievement to design and build a plant today which would be capable of producing a kilowatt-hour per pound of coal of 14,000 B.t.u. heat value, but from a business standpoint it would hardly be profitable when the present day cost of equipment, necessary to achieve such performance, is considered.

In the ultimate analysis, a power plant is really a manufacturing plant for converting fuel into electrical energy, and in the production of electrical energy or power, there are four main costs, namely, materials, maintenance, labor and fixed charges.

In considering the matter of materials, the principal item is fuel, the price of which varies with different locations, depending upon the freight rate, which is affected by the proximity of the source of supply. Consequently, in a plant where fuel is high in cost, more efficiency can be justified than in a plant where fuel is cheap.

Cost of labor decreases as the size or capacity of a plant increases, while in the more complicated plants designed for extremely high efficiencies, the cost of labor is increased, due to necessary additional attendance. The cost of labor per kilowatt-hour, however, does not vary sufficiently to affect the design seriously, except that in all cases simplicity should be foremost in the designer's mind.

Cost of maintenance in the power plant is affected largely by the type of equipment which is installed and consequently the cost of maintenance in the more complicated plants is necessarily higher than it is in plants having more simple equipment.

In considering the matter of fixed charges consisting of interest, taxes, depreciation, etc., it should be remembered that they are constant and must be paid year after year, without being affected by fluctuations in the cost of fuel and labor. It is important, therefore, that a detailed study pertaining to each piece of equipment purchased be made, so as to be reasonably sure that no apparatus is installed that cannot earn its fixed charges.

ITEMS REQUIRING CONSIDERATION

Equipment necessary to a power plant may be divided into two groups, one of which includes the necessary apparatus not affecting the efficiency of the plant and the other group which includes the apparatus which does materially affect the efficiency of the plant. In the study of economical design of steam power plants the major items that merit serious consideration are the fuel burning equipment, boilers and economizers, condensers, feed-water heaters and the auxiliaries necessary to them. Before any intelligent study can be begun, however, the price of fuel and the characteristics of the load under which the plant will operate when finished must be known.

In purchasing apparatus for a power plant, the increment method of considering fixed charges should govern in determining the limit of efficiency and not the average fixed charge on the total investment. In other words, investment should be authorized for betterment in efficiency just as long as the increment of investment for greater efficiency can earn more than its fixed charge.

The design of a power plant should not be faddish and the designer should be careful not to overdo some new thought or idea just to "beat the other fellow."

*Mechanical Engineer, The W. S. Barstow Management Association, Inc.

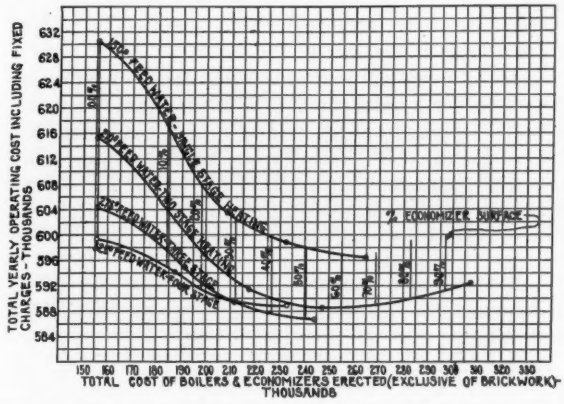

TOTAL YEARLY OPERATING COST INCLUDING FIXED CHARGES - THOUSANDS
TOTAL COST OF BOILERS & ECONOMIZERS ERECTED(EXCLUSIVE OF BRICKWORK)-THOUSANDS
% ECONOMIZER SURFACE

FIG. 1. RELATIVE ECONOMY OF DIFFERENT STAGES OF FEED HEATING WITH 30,000-KW. UNIT OF A 180,000-KW. ULTIMATE CAPACITY PLANT BASED ON 159,000,000 KW-HR. PER YR., 13,500 B.T.U. COAL AT $6.00 PER TON, 1500-HP. BOILERS, FIXED CHARGES AT 17 PER CENT

Study of Boiler and Economizer

In considering the boilers for a plant recently designed, a study was made in order to determine the most economical type and size of boilers, the most economical feed water and flue gas temperatures, as well as the economy to be obtained by the use of economizers.

These boilers were in connection with a 30,000-kw. turbo-generator installed as the first unit of a 180,000-kw. ultimate capacity plant. The study was based on a minimum requirement for each boiler of 74,000 lb. of steam per hr. and a maximum requirement of 100,000 lb. of steam per hr., the boilers to be designed for 350 lb. per sq. in. pressure and 200 deg. F. superheat.

The accompanying curves, Figs. 1, 2, 3 and 4, show some results of this study which pertain to investment and fixed charge.

Curve in Fig. 1 shows the estimated total yearly operating cost including the fixed charges plotted against the total investment necessary for boilers and economizers of various sizes for various stages of feed water heating. The difference in total cost or investment is caused by cost of different sizes of economizers, since the boiler cost remains

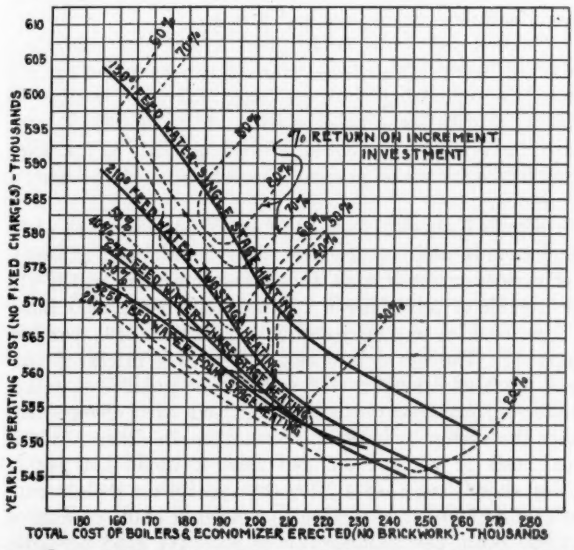

YEARLY OPERATING COST (NO FIXED CHARGES) - THOUSANDS
% RETURN ON INCREMENT INVESTMENT
TOTAL COST OF BOILERS & ECONOMIZER ERECTED(NO BRICKWORK)-THOUSANDS

FIG. 2. THESE CURVES SHOW HOW THE RETURN ON THE INCREMENT INVESTMENT VARIES

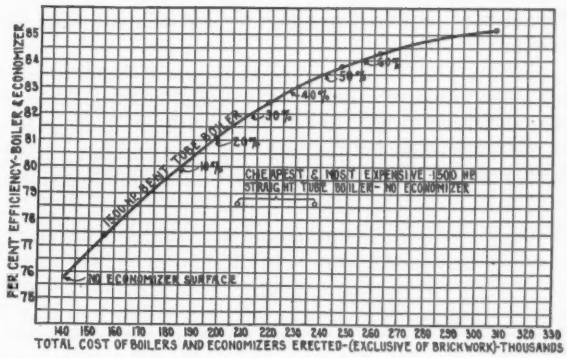

PER CENT EFFICIENCY-BOILER & ECONOMIZER
CHEAPEST & MOST EXPENSIVE 1500 HP. STRAIGHT TUBE BOILER - NO ECONOMIZER
NO ECONOMIZER SURFACE
TOTAL COST OF BOILERS AND ECONOMIZERS ERECTED-(EXCLUSIVE OF BRICKWORK)-THOUSANDS

FIG. 3. CURVE TO DETERMINE MOST ECONOMICAL TYPE OF BOILER AND SIZE OF ECONOMIZER BASED ON 159,000,000 KW-HR. PER YR., 13,500 B.T.U. COAL AT $6.00 PER TON, 212 DEG. F. FEED WATER TEMPERATURE, TWO STAGE HEATING

constant. This curve indicates that three stage heating is most economical where economizers are used in connection with stage feed water heating by means of steam bled from the main turbine. On account of the slight difference in economy, as shown by the curves, between two stage and three stage heating, two stage would probably be selected on account of its greater simplicity of mechanical appliances and of operation. The curve indicates also that where economizers are not considered, four stage heating is justifiable.

Figure 2 shows the estimated yearly operating cost, with the fixed charges not included, plotted against the total investment for boilers and economizers. On this curve are plotted contour lines which show the per cent return on increment investment for the various degrees of feed water heating, and indicate between what limits additional investment for greater efficiency or lower operating cost will produce a given return on the additional investment.

The curve Fig. 3 shows the efficiency of the same size boilers equipped with various sizes of economizers, plotted against the total cost of boilers and economizers. It indicates that where economizers are used, a much less efficient and less expensive boiler can be justified, since efficiency in the boiler is not so important when economizers are used. As the bent tube type of boiler is inherently cheaper than the straight tube type, their use in combination with economizers is unquestionably most economical, even

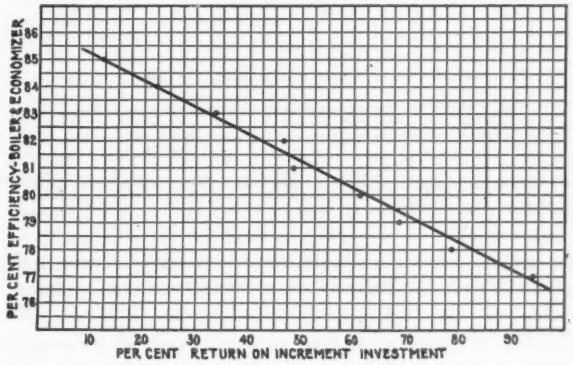


FIG. 4. RELATION BETWEEN PER CENT RETURN ON INCREMENT INVESTMENT AND EFFICIENCY OF BOILER AND ECONOMIZER CONSIDERING A 1500-HP. BOILER ON THE SAME BASIS AS FIG. 3

though they in themselves may be less efficient than the straight tube type.

Figure 4 shows the per cent return on increments of investment necessary to raise the overall boiler and economizer efficiency from a certain percentage of efficiency to a higher percentage for the same set of conditions. It indicates that if 20 per cent return is desired on the last dollar of investment for boilers and economizers, it will not pay to go above 84.2 per cent overall efficiency.

While the above curves show the conclusions for a given set of fixed conditions only, they indicate that if more study is given to the proportion of boilers and economizers a less cost per kilowatt-hour will be the result.

TABLE I. SQUARE FEET OF CONDENSER SURFACE CONSIDERING A WATER VELOCITY IN TUBES OF 6.25 FT. PER SEC.

		30,000 Sq.Ft.		40,000 Sq.Ft.		45,000 Sq.Ft.		50,000 Sq.Ft.	
Month	Water Temp. °F.	Vac. " Hg.	W.R. # per K.W.H.	Vac. " Hg.	W.R. # per K.W.H.	Vac. " Hg.	W.R. # per K.W.H.	Vac. " Hg.	W.R. # per K.W.H.
Jan.	33.5	29.42	9.80	29.55	9.76	29.58	9.75	29.62	9.74
Feb.	36.0	29.38	9.81	29.52	9.77	29.55	9.76	29.59	9.75
Mch.	42.0	29.24	9.85	29.41	9.80	29.46	9.78	29.49	9.77
Apr.	52.5	28.94	9.98	29.16	9.88	29.23	9.86	29.27	9.84
May	65.5	28.42	10.38	28.72	10.12	28.81	10.06	28.89	10.01
June	73.0	28.03	10.77	28.40	10.40	28.52	10.28	28.60	10.21
July	76.5	27.83	10.97	28.22	10.58	28.36	10.44	28.42	10.38
Aug.	75.0	27.92	10.88	28.30	10.50	28.42	10.38	28.51	10.29
Sept.	70.0	28.20	10.60	28.49	10.31	28.65	10.17	28.73	10.11
Oct.	60.0	28.67	10.16	28.93	9.99	29.01	9.95	29.07	9.92
Nov.	47.0	29.11	9.90	29.30	9.83	29.36	9.81	29.40	9.80
Dec.	36.0	29.34	9.82	29.48	9.78	29.52	9.77	29.56	9.76
Total	669.0		122.92		120.72		120.01		119.58
Avg.	55.75		10.24		10.06		10.00		9.965

Determining the Proper Size of Condenser

Knowing the effect of vacuum on the operation of the main turbine and the extent to which this vacuum may be utilized, the seasonal circulating water temperatures, and the daily load, the proper size of condenser can be determined.

Table I, Table II and curve Fig. 5 show some results of a condenser study covering a surface condenser for a 30,000-kw. turbo-generator. The study was based on a 27,500-kw. load on a 30,000-kw. unit, 280,000 lb. of steam condensed per hour, and 159,000,000 kw-hr. per year generated. The study included both the single pass and the two pass types of condenser.

Table I shows an analysis of calculated vacuums and water rates for a year, based on average monthly circulating water temperatures for various sizes of condenser. The figures were calculated from turbine and condenser manufacturers' guarantees. From this tabulation and others, curve Fig. 5 was drawn showing yearly operating cost plotted against various sizes of condensers for different velocities of water through the tubes. The yearly operating costs were determined from the average water rate.

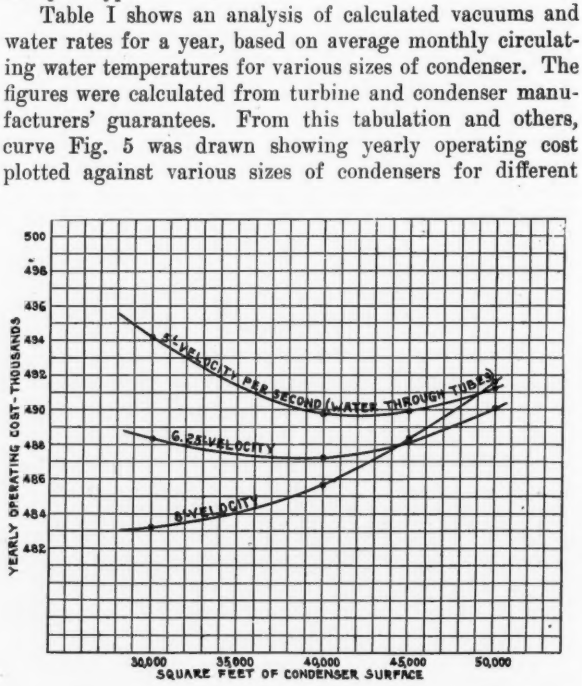


FIG. 5. CURVES DRAWN TO DETERMINE YEARLY OPERATING COSTS WITH VARIOUS AMOUNTS OF CONDENSER SURFACE FOR FIRST 30,000-KW. UNIT OF A 180,000-KW. ULTIMATE CAPACITY PLANT BASED ON 27,500 KW. LOAD ON A 30,000-KW. TURBO-GENERATOR, 280,000 LB. OF STEAM CONDENSED PER HOUR, 159,000,000 KW-HR. PER YR. GENERATED, SINGLE PASS CONDENSER

TABLE II. ANALYSIS OF A SERIES OF QUOTATIONS FROM COMPETITIVE MANUFACTURERS

		Mfr. "A"		Mfr. "B"		Mfr. "C"		Mfr. "D"		Mfr. "E"		Mfr. "F"	
Month	Water Temp.	Vac. " Hg.	W.R. # per K.W.H.	Vac. " Hg.	W.R. # per K.W.H.	Vac. " Hg.	W.R. # per K.W.H.	Vac. " Hg.	W.R. # per K.W.H.	Vac. " Hg.	W.R. # per K.W.H.	Vac. " Hg.	W.R. # per K.W.H.
Jan.	33.5	29.20	9.86	29.25	9.85	29.25	9.85	29.47	9.78	29.33	9.82	29.00	9.95
Feb.	36.0	29.20	9.86	29.25	9.85	29.25	9.85	29.47	9.78	29.33	9.82	29.00	9.95
Mch.	42.0	29.20	9.86	29.25	9.85	29.25	9.85	29.44	9.78	29.29	9.83	29.00	9.95
Apr.	52.5	29.17	9.86	29.22	9.86	29.15	9.88	29.23	9.85	29.09	9.95	29.00	9.95
May	65.5	28.80	10.06	28.87	10.02	28.85	10.03	28.79	10.06	28.76	10.09	28.6	10.06
June	73.0	28.50	10.30	28.56	10.25	28.59	10.22	28.45	10.34	28.50	10.30	28.50	10.30
July	76.5	28.37	10.45	28.44	10.36	28.47	10.32	28.30	10.50	28.36	10.45	28.37	10.45
Aug.	75.0	28.40	10.40	28.47	10.32	28.50	10.30	28.35	10.48	28.40	10.40	28.40	10.40
Sept.	70.0	28.52	10.30	28.59	10.14	28.70	10.13	28.59	10.22	28.61	10.20	28.52	10.30
Oct.	60.0	29.00	9.95	29.05	9.92	29.00	9.95	29.00	9.95	28.92	9.99	29.00	9.95
Nov.	47.0	29.18	9.88	29.25	9.85	29.21	9.86	29.35	9.81	29.20	9.87	29.00	9.95
Dec.	36.0	29.30	9.86	29.25	9.85	29.25	9.85	29.47	9.78	29.33	9.82	29.00	9.95
Total	669.0	344.84	120.56	347.55	120.02	347.46	120.09	347.90	120.32	347.11	120.50	345.69	121.06
Avg.	55.75	28.90	10.05	28.96	10.01	28.95	10.00	28.99	10.03	28.92	10.04	28.81	10.09
Main Unit Yearly Coal Cost		479,385		477,477		477,000		478,430		478,908		481,290	
Circulating Pump Coal Cost		13,400		14,100		17,100		14,300		13,200		17,300	
Tube Maintenance		3,150		3,150		1,980		3,150		2,940		3,115	
Fixed Charges		13,750		14,000		17,500		18,600		14,480		16,890	
Total Yearly Operating Cost		$ 509,685		$ 508,727		$513,630		$ 514,080		$ 509,918		$ 518,595	

From this study, the conclusion is that in the past, condensers of too large tube surface have been installed. Although it is possible to approximate the correct size of condenser from calculations of known heat transfer, the most economical size should be chosen from an analysis of manufacturers' guarantees and prices.

Table II shows an analysis of a series of quotations received from competitive manufacturers including the calculated operating costs and fixed charges. A table of this kind with some consideration of the merits of each manufacturer's equipment and its adaptability to the plant design should make possible the selection of the proper equipment.

Figure 6 shows a relation of B.t.u. per kw-hr. to plant performance and construction costs per kilowatt capacity, for various prices of coal. It is based on a plant which will be capable of producing a kilowatt-hour per 17,000 B.t.u. in the coal, at a total construction cost of $135 per kw. capacity. The curve indicates for various prices of coal how much additional investment may be justified to attain better performance until the additional fixed charges balance the saving by better performance. In other words if coal costs $3 per net ton delivered, it would not pay to invest more than $148 a kilowatt capacity for a plant capable of 13,000 B.t.u. performance when a plant capable of 17,000 B.t.u. performance can be built for $135 per kilowatt capacity. Although construction costs per kilowatt

capacity will vary with the location of the plant, the relation of increased cost per kilowatt capacity and better performance will remain approximately as shown on the curve. The basic figures of 17,000 B.t.u. performance and construction cost of $135 per kilowatt capacity were taken from actual figures on a first 30,000-kw. unit of a 180,000-kw. ultimate capacity plant. When additional units are installed, it is expected that the construction cost per kilowatt will not exceed $110 and the performance will reduce to 16,000 B.t.u. per kw-hr. or less.

In conclusion, recent studies of boilers, economizers, turbines, condensers, piping, and actual results would indicate that with known apparatus, methods and prices of

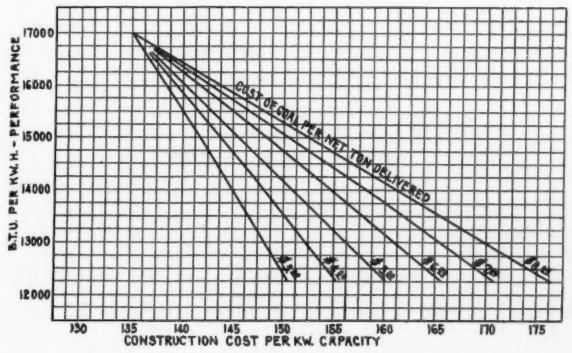


FIG. 6. ECONOMICAL POWER PLANT COST PER KW. CAPACITY, BASED ON OPERATING PERFORMANCE OF 17,000 B.T.U. PER KW-HR., COAL OF 13,500 B.T.U. PER LB. AS RECEIVED, CONSTRUCTION COST OF 17,000-B.T.U. PLANT AT $135.00 PER KW. CAPACITY, SAVING ON COAL CAPITALIZED AT 15 PER CENT, LOAD FACTOR 50 PER CENT. NO ALLOWANCE WAS MADE FOR INCREASED COST OF OPERATION DUE TO MORE EXPENSIVE AND COMPLICATED PLANTS

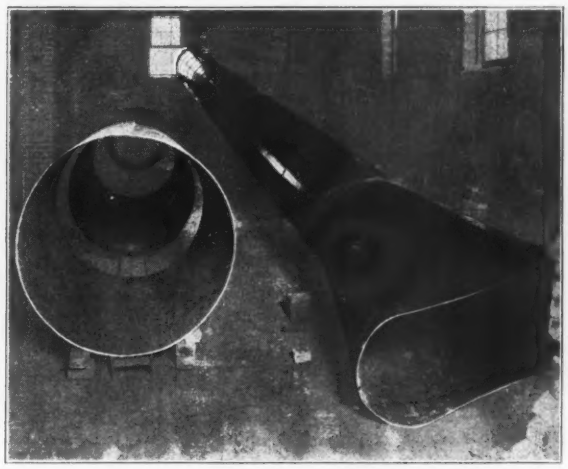
today, coal at $6 a ton and 50 per cent load factor, pressures above 400 lb. and operating results below 16,000 B.t.u. per kw-hr. are too expensive and are not sound business propositions.

Welding of Steel Stacks Prevents Corrosion

WHEREVER STEEL stacks can be used, many engineers prefer them on account of their low first cost and the ease with which they can be erected. Self-supporting stacks are commonly used for sizes over 5 ft. diameter and 125 ft. in height. Guyed stacks in smaller sizes than this are often fabricated by welding, instead of riveting, and much of the trouble caused on these stacks by corrosion at the joints can thus be prevented. This corrosion, caused by sulphurous gases in the stack combining with moisture, usually shortens the life of the stacks by many months. Often it can be prevented by having the circumferential seams all point down; this may be done in the case of a new stack but even so, the longitudinal seams may give trouble. A much better way, says Oxy-acetylene Tips, is to weld the stack into a strong, corrosion-resisting cylinder of steel.

Steel stacks on tugs and river boats stand much more abuse than those on land. In addition to the acid corrosion and wind pressure, they must stand severe shocks, from pitching, bumping and vibration. Welded stacks used for this service have shown no signs of deterioration after 3 yr. of such service, although the normal life of such stacks is 2 yr.

Most welded stacks are made up in the same way. The plates, after being cut, are prepared by first beveling the edges, if the material is over ⅛ in. thick. This may be done by machine or with the cutting blow-pipe. Plates are usually formed in bending rolls. Next the longitudinal seams are welded. Several of the completed cylinders are then lined up on cradles or tracks of some kind, as indicated in the illustration and joined into a continuous cylinder by welding circumferential seams. In welding these seams, care must be taken to tack them in several places around the circumference before starting the joints, so that they will line up properly. An experienced welder should know the proper precautions to take in making up these joints.



SECTIONS ARE LINED UP ON PROPER SUPPORTS AND WELDED INTO A CYLINDER AS SHOWN AT RIGHT

One advantage of using a welded stack is that if it should be slightly dented while joining sections or in transportation, the dented section can be heated and easily hammered back into shape. With a riveted stack, on the other hand, it may be necessary to remove some rivets in order to take out the dent. The principal advantage of the welded stack, however, is that all worry about joints, or necessity for having all the circumferential laps point down, is eliminated, because the welded stack is one continuous cylinder of steel.

DURING the past few years, there have been installed many more vertical hydro-electric units than horizontal units, according to M. C. Olson in a paper read to the Hydro-Electric Power Conference at the Engineer's Club of Philadelphia. A curve was drawn showing the relative percentage of the vertical capacity in kv.a. to the total capacity of hydro-electric generators, using only data concerning those installed by the General Electric Co. In 1922, the total vertical and horizontal generator capacities were about equal, the horizontal type being slightly in the lead. In 1923, the percentage of vertical generator capacity was 75 per cent of the total hydro-electric generator capacity and in 1924 it was 86.5 per cent. This shows the tendency of engineers to prefer vertical to horizontal units.

High Pressure Underground Steam Systems Are Increasing

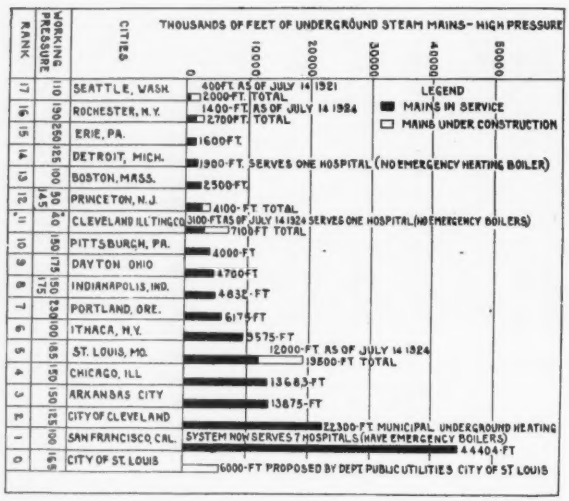
By Louis A. Foster

IN THE PAST, the subject of district steam heating has been localized almost entirely to engineering groups; but, today, the wide awake, progressive cities and their representative business leaders are realizing its possibilities. This fast developing medium has finally emerged from the experimental stage and now stands solidly on its own feet. Recent issues of financial as well as technical publications are discussing the subject freely and the development has taken definite form in four general groups which can be summarized as follows:

1. The company organized solely for the purpose of generating and selling steam.

2. The electric light company, generating electricity with steam and selling the exhaust and surplus steam.

CHART I. HIGH-PRESSURE STEAM MAINS IN THE UNITED STATES


RANK
WORKING PRESSURE
CITIES
THOUSANDS OF FEET OF UNDERGROUND STEAM MAINS - HIGH PRESSURE
0
10000
20000
30000
40000
50000
LEGEND
MAINS IN SERVICE
MAINS UNDER CONSTRUCTION
17 110 SEATTLE, WASH. 400 FT. AS OF JULY 14 1921 2000 FT. TOTAL
16 150 250 ROCHESTER, N.Y. 1400 FT. AS OF JULY 14 1924 2700 FT. TOTAL
15 ERIE, PA. 1600 FT.
14 125 DETROIT, MICH. 1900 FT. SERVES ONE HOSPITAL (NO EMERGENCY HEATING BOILER)
13 100 150 BOSTON, MASS. 2500 FT.
12 PRINCETON, N.J. 100 FT. TOTAL
11 145 150 CLEVELAND ILLUMINATING CO 3100 FT AS OF JULY 14 1924 SERVES ONE HOSPITAL (NO EMERGENCY BOILERS) 7100 FT TOTAL
10 150 PITTSBURGH, PA. 4000 FT
9 175 DAYTON OHIO 4700 FT
8 150 175 INDIANAPOLIS, IND. 4832 FT
7 PORTLAND, ORE. 6179 FT
6 200 ITHACA, N.Y. 9575 FT
5 150 ST. LOUIS, MO. 12000 FT AS OF JULY 14 1924 19500 FT TOTAL
4 150 CHICAGO, ILL. 13683 FT
3 150 ARKANSAS CITY 13875 FT
2 CITY OF CLEVELAND 22300 FT MUNICIPAL UNDERGROUND HEATING
1 100 150 SAN FRANCISCO, CAL. SYSTEM NOW SERVES 7 HOSPITALS (HAVE EMERGENCY BOILERS) 44404 FT
0 165 CITY OF ST. LOUIS 6000 FT PROPOSED BY DEPT PUBLIC UTILITIES CITY OF ST LOUIS

3. A community heating plant for a group of residences.

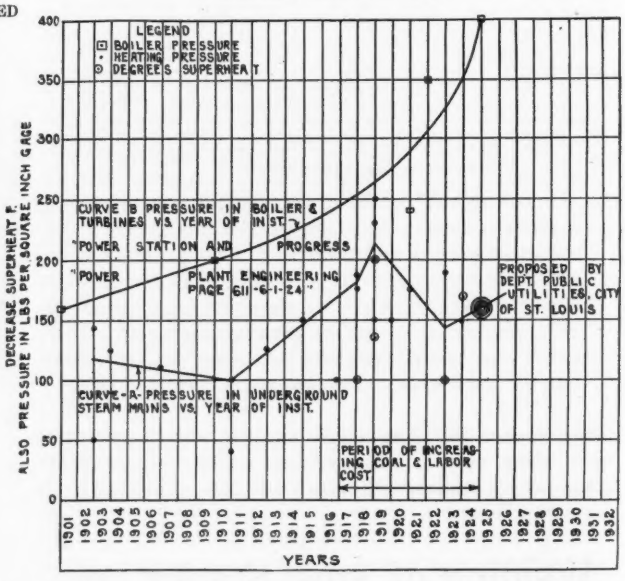
4. A central plant for institutions, municipal buildings, hospitals or industrial plants.

Economics and science have played major parts in the growth and development of these agencies, but due credit must be given to those individuals who, since the original conception some 48 yr. ago, have, by their steadfastness, been responsible for the wonderful development of the industry as it stands today. The original low-pressure exhaust steam systems, some of which are 30 yr. old, are still giving first class service. But the ever increasing demand for service has brought forth a new phase, the high-pressure distribution system now existing in practically every large city.

Chart I, compiled in 1924, represents graphically the extent of the high-pressure underground steam lines throughout the United States, which can be considered the milestone of the first decade of the industry. This chart covers practically all the major cities with the exception of New York, which is not included. That city leads all those listed here as it now has about 170,000 ft. of underground high-pressure lines, serving both business and residential sections. It is interesting to note that, of the seventeen cities listed, only two show a working steam pressure less than 100 lb., while there are nine listed which have a working pressure of over 150 lb., with the maximum 250 lb. Six of this group of installations are using superheated steam. There are, of course, other high pressure systems which are not shown here, as the information was not at hand when this study was made. Those at all familiar with underground steam construction will at once appreciate that these systems represent literally millions of dollars invested.

Chart II gives further light upon the change in use of high-pressure for underground lines, as the various systems illustrated in Chart I are plotted upon the year of installation and against working pressure used. From 1916 to 1924, there was a notable increase in the number of high-pressure installations, which parallels closely the period of increased coal and labor costs.

CHART II. INCREASE OF PRESSURES FOR HEATING AND FOR BOILERS, 1901 TO 1925


LEGEND
BOILER PRESSURE
HEATING PRESSURE
DEGREES SUPERHEAT
DECREASE SUPERHEAT F.
ALSO PRESSURE IN LBS PER SQUARE INCH GAGE
400
350
300
250
200
150
100
50
0
CURVE B PRESSURE IN BOILER & TURBINES VS. YEAR OF INST.
"POWER STATION AND PROGRESS"
"POWER PLANT ENGINEERING PAGE 611-6-1-24"
PROPOSED BY DEPT PUBLIC UTILITIES CITY OF ST. LOUIS
CURVE-A-PRESSURE IN UNDERGROUND STEAM MAINS VS. YEAR OF INST.
PERIOD OF INCREASING COAL & LABOR COST
1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932
YEARS

Some relation is shown between the increase of pressure used underground and that used in boilers and turbines up to 1918, but the underground pressures lag behind the boiler pressures. From 1918 to 1922, there was a falling off in pressures used but they are now on the increase again.

It would seem evident that the use and development of high-pressure underground lines will advance rapidly during ensuing years. As evidence of this, one only has to call to mind the notable installations which are under way at this time. New York City is doing extensive work along this line, while Cleveland, Dayton, Rochester, St. Louis, Pittsburgh, Detroit, Boston and many other cities are active in this work.

If the service rendered in these days of electricity and steam for citizens of the United States were performed entirely by hand power, it would require 30 slaves for every person in the country, according to a statement by the Smithsonian Institute.

Baffle walls in boilers generally receive scant attention from the average operator although they are an exceedingly important component of the boiler setting.

Pulverized Fuel in European Plants

HIGH EFFICIENCIES OBTAINABLE ARE LEADING ENGINEERS TO PULVERIZED FUEL IN NEW AND OLD PLANTS. BY C. H. S. TUPHOLME

GROWTH OF pulverized fuel firing in Britain is shown by the fact that, during 1924, equipment was ordered for the firing of boilers totaling about 165,000 sq. ft. of heating surface, twice that existing or ordered during 1923, said W. J. Cotterell, at a meeting of the Nottingham Society of Engineers. One of the largest contracts carried

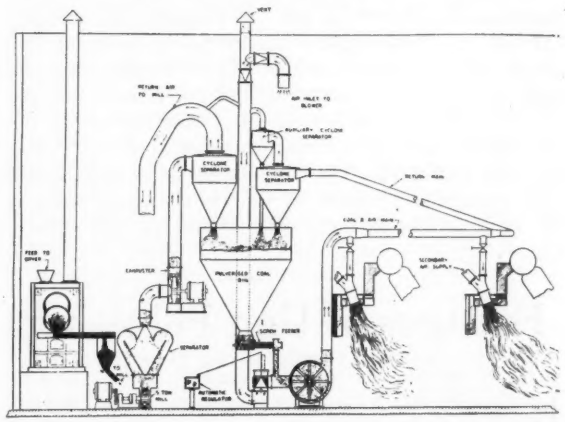


FIG. 1. HOLBECK SYSTEM AS APPLIED AT HAMMERSMITH STATION

out was 25,000 sq. ft. on the indirect or storage system for the Hammersmith Electricity Supply Station.

British power plant engineers have found that in the case of a good system of pulverized fuel firing, properly installed, the maximum efficiency of combustion is closely

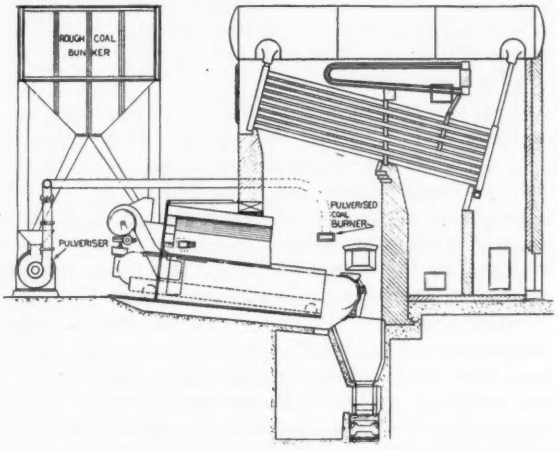


FIG. 2. AMSTERDAM ELECTRICITY STATION BURNS COAL ON GRATE AND IN PULVERIZED FORM

approached. The amount of excess air is only from 20 to 25 per cent, compared with 40 to 50 per cent with many of the modern stokers—equivalent to 16 to 16.5 per cent carbon dioxide compared with 13 or 14 per cent in the gases leaving the furnaces.

At the Hammersmith station the Holbeck system is used, as shown in Fig. 1. At this plant the coal is dried in a rotary drier down to 1 per cent of moisture before pulverizing. The fine coal is drawn from the mill by air separation and delivered through a collector to a storage bin from which it is taken by screws into the air stream on the suction side of the blower. The coal, with the primary air as the conveying medium, is blown through a duct to a further collector on the pulverized coal bin, branch pipes being taken from the duct to the boilers. By means of an automatic regulator the ratio of coal and air is kept constant, irrespective of the demands of the boilers being fired. The secondary air is added at the burners.

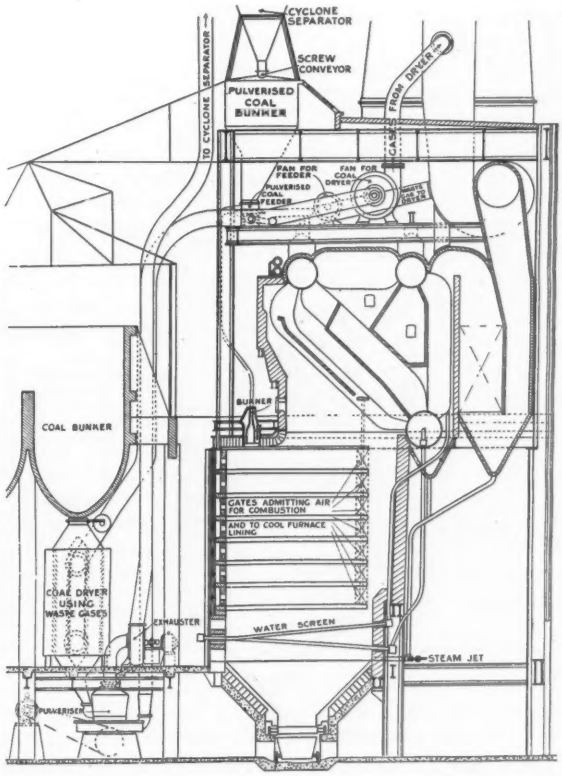


FIG. 3. VITRY STATION HAS FEATURES RESEMBLING AMERICAN PRACTICE

At the Hammersmith station a Bonnot mill was used with the first part of the plant, but it proved to be extremely noisy in operation with high power consumption and maintenance costs. A Sturtevant mill has now been installed in which the coarse material is taken away with the fines and elevated to a separator, the oversize being returned to the mill.

One application of the direct firing system is in combination with an existing mechanical grate, a system which is now being employed at the Amsterdam Electricity Station (see Fig. 2). At this plant a high speed pulverizer supplies coal to a number of burners over the back end of the grate so that the flames pass at right angles over the top of the grate surface. The pulverizer is adjusted so that much less air than usual is passed through the machine and at the burners there is not sufficient air for

complete combustion; consequently the excess air from the mechanical stoker is utilized to complete the combustion of the pulverized fuel, resulting in a high combined efficiency. At this plant one of the chief defects of the stoker has been eliminated—the excess air that usually passes through the ash and clinker at the end of the stoker being used. Due to the limited size of the combustion chamber it is possible to burn only a relatively small amount of pulverized fuel; but, owing to its extreme flexibility, it can be used for any variations in load, while the evaporating capacity of the boilers can be increased by 15 to 20 per cent.

The Vitry Station of the Union d'Electricite near Paris is the largest plant operating in Europe and is constructed along the lines of the latest pulverized fuel firing

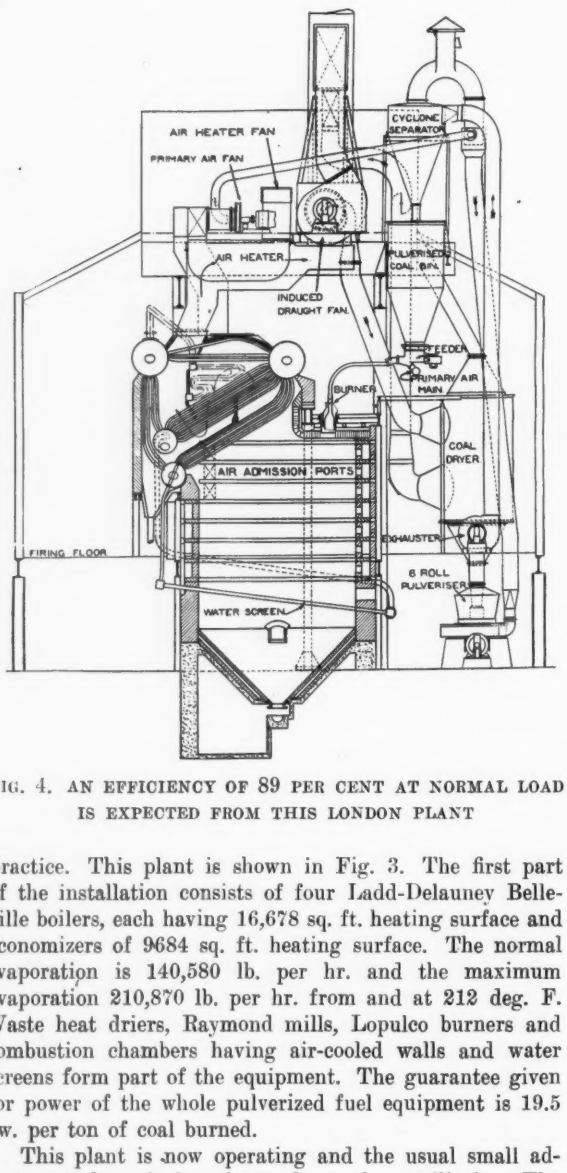


FIG. 4. AN EFFICIENCY OF 89 PER CENT AT NORMAL LOAD IS EXPECTED FROM THIS LONDON PLANT

practice. This plant is shown in Fig. 3. The first part of the installation consists of four Ladd-Delauney Belleville boilers, each having 16,678 sq. ft. heating surface and economizers of 9684 sq. ft. heating surface. The normal evaporation is 140,580 lb. per hr. and the maximum evaporation 210,870 lb. per hr. from and at 212 deg. F. Waste heat driers, Raymond mills, Lopulco burners and combustion chambers having air-cooled walls and water screens form part of the equipment. The guarantee given for power of the whole pulverized fuel equipment is 19.5 kw. per ton of coal burned.

This plant is now operating and the usual small adjustments have had to be made to the auxiliaries. The following extract from the operating engineer's first report is of interest from a practical point of view:

"The burners were lit two by two and a boiler pressure of 200 lb. per sq. in. was obtained in an hour. An evaporation of 120,000 lb. per hr. was reached and from 5 to 8 boilers in the old boiler house were taken off. Tests showed 16.5 per cent carbon dioxide in the first pass of the boiler. One boiler has been on the line for a week without incident. We are running without smoke."

The results of the plant now being constructed for the North Metropolitan Electric Power Supply Co., London, will also be awaited with interest. Here a Clayton bent tube boiler of 7200 sq. ft. heating surface will be fitted with Lopulco equipment and an Usco air heater. The guarantees in the case of this plant are of interest. The evaporations based on coal of 10,000 B.t.u. are 75,500 lb. per hr. normal and 101,000 lb. per hr. maximum from and at 212 deg. F. These evaporations represent 10.5 and 14 lb. per sq. ft. of heating surface. The efficiency on normal load is 89 per cent taken on the net calorific value of the coal. Combustion is to be practically smokeless. Power is not to exceed 2 per cent when allowing 20,000 B.t.u. per unit generated. The instrument board will be fitted with push button remote control for the coal feeders and air supply. The side elevation of this plan is shown in Fig. 4.

Features of Unit Pulverizers

Many Manufacturers Favor Unit Systems

REVIEW OF THE present pulverized fuel situation discloses many interesting and sometimes conflicting views. At a meeting of the American Society of Mechanical Engineers held recently in New York City, it was revealed that many manufacturers are concentrating their efforts on the unit system and much of the present day research is being done with this type of pulverization.

While pulverized coal has been effectively used for nearly 30 yr., the successful application to steam boilers may be said to have developed almost entirely in the last 6 yr. This has been, for the most part, an economic development. High stoker efficiencies are possible with good grades of coal, but these coals are not economically available for every plant.

Unit pulverizers are practically independent as to character of fuel, so that their use has made highly efficient operation possible with cheap fuels not suitable for stokers. The increasing cost of fuel oil has been an additional factor so that many new boiler plants today are being designed either for pulverized fuel or may be easily converted to this means of firing. Old plants are being adapted to its use and it is particularly this phase of application that gives the unit system its greatest field of usefulness. The installation of equipment such as overhead bins, driers, exhausters, conveyors, feeders, and motors which are needed for the storage system, is often impossible in old plants, whereas unit systems, due to their compactness and simplicity of operation, may easily be installed in any plant.

The unit system should conform to the following requirements: Moderate initial cost, compact design, low power consumption, fine pulverization, ability to handle fuels with wide range of moisture content and foreign material, sturdy construction which insures against shut-downs and undue wear, low cost of maintenance and uniform efficiency.

Initial costs are reported as much less than with the bin system and comparing favorably with stoker firing.

Floor Space an Important Item

One of the leading features of unit pulverizers is the compactness of design. Manufacturers are continually striving for this and the degree in which they have succeeded may be shown by the fact that, a little more than 2 yr. ago, a unit pulverizing system of 3000 lb. per hr. capacity, occupied 41 sq. ft. of floor space, while today machines of 8000 lb. capacity occupy only 38 sq. ft. of floor space. In terms of output this means that the machine of today, occupying the same floor space as the one of 2 yr. ago, will do three times as much work.

Power Consumption Being Reduced

There has also been a marked reduction in power consumption in recent developments. Where it required 17 kw-hr. per ton for the 3000-lb. machine of 2 yr. ago, today an 8000-lb. machine can be operated at full load with 13 kw-hr. per ton. This has been accomplished in a large measure by multi-stage velocity air chambers, through which the fine powder is carried away as fast as formed. There is considerable variation in power consumption of different unit systems, depending on the hardness of the fuel, the amount of moisture and the degree of fineness obtained. The power consumption varies over a wide range, although 15 to 20 kw-hr. may be considered economical operation.

There is a disagreement among manufacturers as to the most efficient method of pulverization. Some say hammer mills which grind in suspension are the best, others advocate grinding by sliding one surface over another, while others think the ball-type of mill the most economical.

Difference of Opinion as to Fineness

There is also considerable difference of opinion among manufacturers as to the degree of fineness needed for the most efficient operation. This, of course, is largely dependent upon the furnace design and the method employed in injecting the fuel into the furnace. The generally accepted standard of pulverization is the amount, expressed in per cent, which will pass through a 200-mesh screen. Pulverization as now employed by the various types, varies from 50 to 90 per cent through a 200-mesh screen. The generally accepted average seems to be about 75 per cent. Some think that this is the most effective point and that finer pulverization will really do more harm than good since, in order to have efficient combustion, each fuel particle must be enveloped by the required amount of oxygen, which will be materially reduced if the fuel particles are made smaller. When the particles are crowded too closely together, the effect is really an approach to a solid sheet of coal with less chance for oxygen to envelop each particle.

On the other hand, some engineers think that the finer the fuel is ground, the better. They say that the pulverization of coal must be compared to the atomization of oil in a carburetor and that combustion conditions are analogous. In one plant where exceptionally fine results are obtained they attribute this to the fineness of pulverization—94.5 per cent through a 200-mesh screen.

Unit pulverizers are now being built to handle coal up to 15 or 18 per cent moisture and some manufacturers state that their machines are of such sturdy construction that magnetic pulleys for removing tramp iron are not necessary. They point out that a magnetic pulley is often ineffective since it will not remove brass or copper or manganese steel.

Probably the main disadvantage of the unit pulverizer is the fact that if something goes wrong and the machine is stopped the fire will go out. To minimize this difficulty, these machines must be made so that repairs can be made in a hurry and all working parts reached in the shortest possible time. Machines are now being built in such a way that practically all repairs can be made in an hour to an hour and a half.

Maintenance Costs Being Reduced

Maintenance costs are not only being reduced by sturdier construction, but the ease with which repairs can be made is being recognized as an important factor. Cast-iron shells of the older designs are being replaced with steel, which eliminates the danger of fracture by tramp iron or other foreign material. Large steel alloy shafts mounted on heavy duty ball or roller bearings further eliminate the danger of bent shafts and bearing troubles, reduce vibration and give lower power consumption than the former plain bearings. Interior wearing parts are of manganese steel which insures long life. Continuous operation for periods of 6 to 8 mo. are usual for average bituminous coals, while with eastern coals such as Pocahontas, New River and Georges Creek, 8 to 12 mo. periods are reported.

When discussing combustion efficiency proponents of pulverized fuel point to the absence of any banking loss and the almost flat efficiency curve of pulverized fuel furnaces as conditions which contribute to high average efficiencies over long periods.

Recently The Revue Universal des Mines of Liege, Belgium, described some experiments made by K. W. Schwartz, which show that a coating of chromium protects iron from corrosion. The specimens treated were subjected to several weeks' exposure to the atmosphere in a chemical laboratory and to three weeks' immersion in water. They showed abosolutely no trace of corrosion. The chromium is deposited electrolytically; the method being to use anodes of chromium, the electrolyte containing chromic acid and sulphate of chromium.

In New York State an unusual situation has arisen between the Lawrence Park Heat, Light & Power Co. and the Westchester Lighting Co. The former is owned by a real estate concern which has among its holdings Hotel Gramatan, lighted and heated from an individual separate plant. It is now planned to erect 12 new apartments, housing 350 tenants, near the hotel and supply heat and light from the same plant by means of pipes and conduits crossing public streets for which franchise has been granted. The Lawrence Park Co. states that it intends to furnish service only to its own buildings and that it can make the electric current as a by-product of the heating, thus reducing cost to tenants.

Westchester Lighting Co. has a franchise to light Bronxville and claims that the proposed lighting conduits will be a duplication, harmful to its business, hence are opposing the permit to the Lawrence Park Co. in the hearings before the Public Service Commission.

Decision of this case would seem to affect the rights of all "block" heating systems in New York State, where a central station is already furnishing current, although it seems unlikely that any question would arise where wires or conduits do not cross or run in public streets or alleys.

Recent Hydraulic Turbines for High Heads

LATEST DESIGNS OF HYDRO-ELECTRIC PLANTS USING BOTH REACTION AND IMPULSE TURBINES SHOW HOW THE EXACTING REQUIREMENTS OF THIS SERVICE ARE MET

DURING THE past few years, the two phases of hydraulic turbine practice that have most engaged the attention of engineers are the installation of large units of high efficiency such as those of the Niagara Falls Power Co., and the successful operation of reaction runners at heads of 800 to 900 ft. and impulse wheels under heads up to 1900 ft., with several designs now under construction for higher heads. It is the intention of this article to

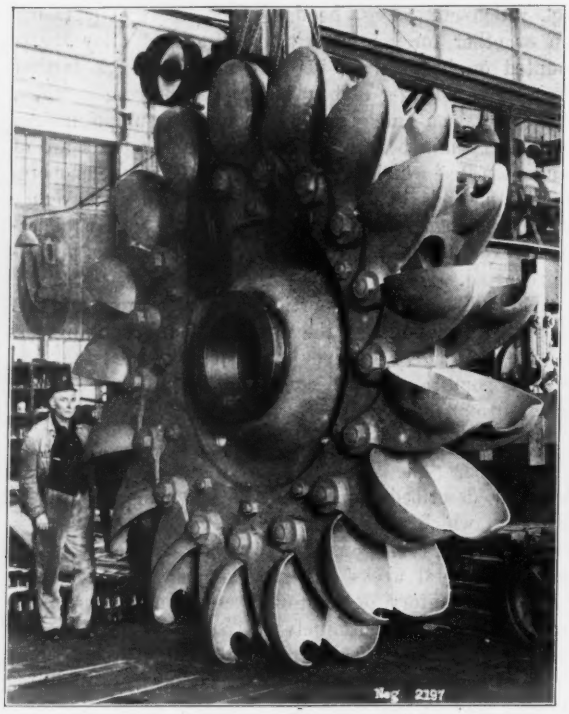


FIG. 1. CHAIN TYPE CONSTRUCTION GIVES STRENGTH TO 25,000-HP. PELTON RUNNER

discuss only a few of the recent applications of turbines to high heads. These developments have taken place for the most part in the Western states, on account of the physical characteristics of the topography.

MANY LARGE IMPULSE TYPE UNITS ARE IN USE

Modern large capacity impulse type units are often of the double overhung type with auxiliary relief nozzles. So far the largest units of this type have been of 35,000 hp. at an effective head of 1900 ft. and a speed of 300 r.p.m. Studies, however, have been made for single units of 70,000 hp. at 2100 ft. head, and it is likely that machines of this size will be built in the near future. Units of this size are used on large interconnected systems, therefore the question of speed regulation is not always as serious as it would be under other conditions. Then too, since the weight of a large rotating element—generator rotor and water wheel runner—may be as much as 130 or 135 T., the flywheel effect is of material help. In such wheels, the centrifugal force developed by the buckets, which may weight 1200 to 1500 lb. each, is large; in order to secure well fitted connections of buckets to wheel within the limited size of the bucket lugs, the chain type bucket fastening has been developed, as shown in Fig. 1. The runner has a fork-shaped cross-section at the rim; the space between the forks is occupied by the front lugs of the buckets while the rear lugs straddle the rim. One bolt then passes through the rear lugs of one bucket, the two sides of the wheel rim and the front lug of the next bucket. On account of the need for securing buckets so firmly to the water wheel runners, the process is not simple when done with the average power house facilities. To reduce this labor, runners are often made with replaceable rims—that is, rims on which complete sets of buckets are fastened. A complete rim can then be slipped off and a new one put in its place much like the demountable rim of an automobile tire.

Speed regulation of the Pelton wheel is usually obtained with a needle nozzle, which may be equipped with an

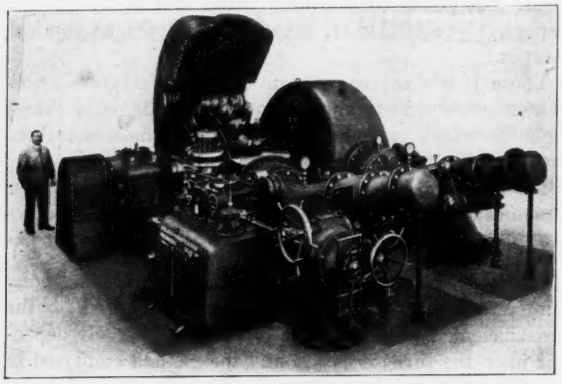
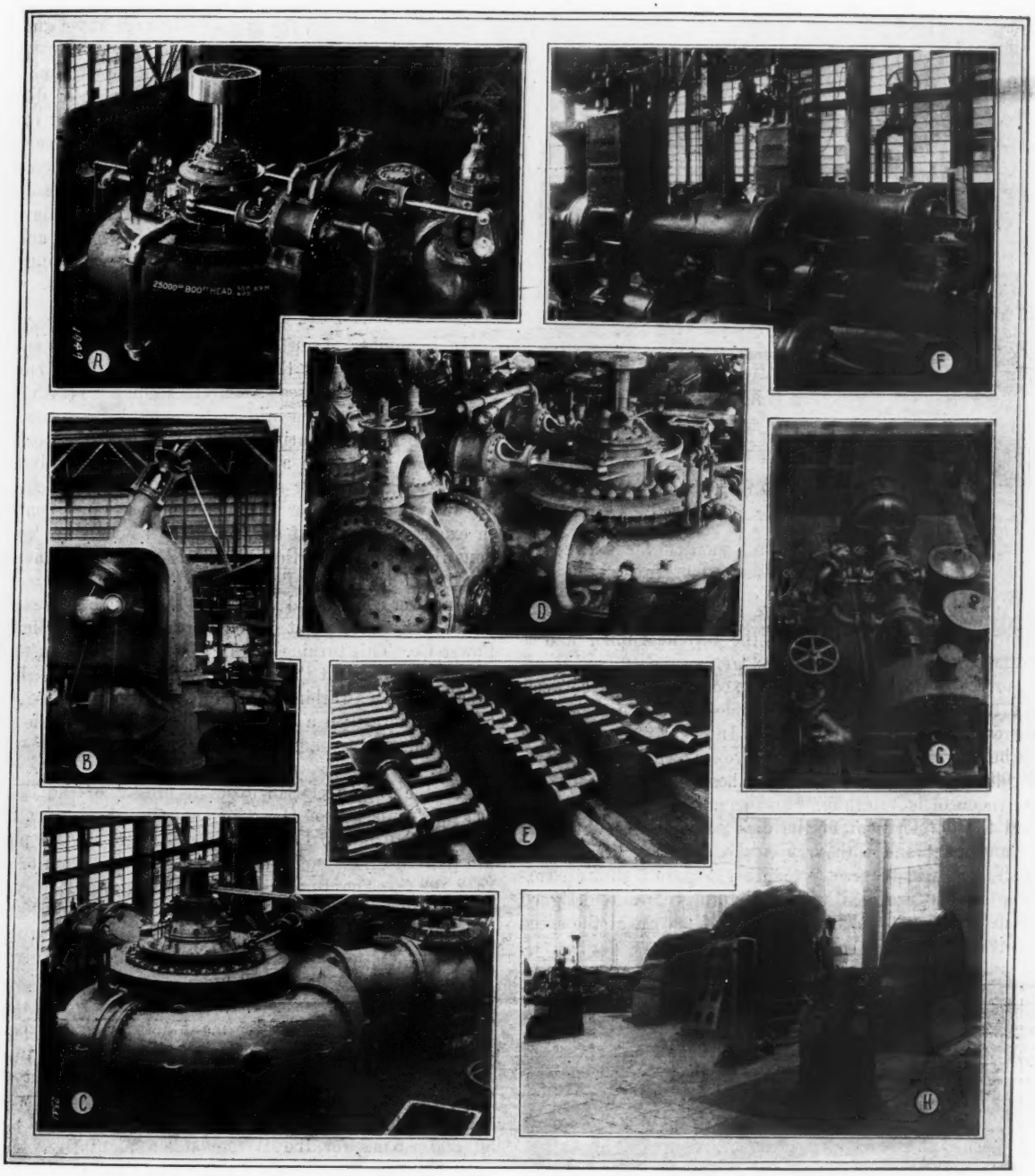


FIG. 2. DOUBLE ROTOR PELTON WHEEL AT AMSTEG, SWITZERLAND

auxiliary relief. A main power nozzle varies the supply of water according to load demands and a relief nozzle prevents undue pressure rise in the penstock, which might result from velocity changes. Obviously the two nozzles must have similar discharge characteristics. Suitable servomotors and dashpots are provided for proper inverse action of these nozzles. In plants where no water economy is desired or where conditions require stream flow operation, the matter of speed regulation is more simple. The governor operates a stream deflector as shown in Fig. 3B, which prevents all or part of the jet from striking the buckets in case the load goes off. A nozzle with motor or hand operated needle adjusts the jet diameter to take care of variations of stream flow.

PELTON WHEELS IN EUROPE

Pelton wheel practice in Europe is essentially the same as in this country. In some parts of Europe the heads are high and wheels of the type shown in Fig. 2 are used. This is a double rotor wheel in use at the Amsteg plant of the Swiss Federal State Railway under a head of 902 ft., at a speed of 333⅓ r.p.m. Needle nozzles are used with deflectors, somewhat similar to American practice, the governors and servomotors being also much the same. Generation is



Photographs by The Pelton Water Wheel Co.

FIG. 3. RECENT HIGH HEAD INSTALLATIONS SHOW MANY REFINEMENTS

A—Two of these 25,000 hp. units operate on stream flow basis at Kern River No. 3. B—Deflectors modify jets for speed regulation of impulse wheel under stream flow operation. C—Pit River No. 3 plant uses 33,000-hp. reaction turbines. D—The Oak Grove unit is equipped with a butterfly valve at the casing inlet. E—Disk type guide vanes aid in reducing leakage. F—Double overhung Pelton wheel for 1900-ft. head uses these needles and governors. G—Pit River No. 3 units have individual oil sets for each unit. H—Double overhung, single nozzle Pelton wheel has capacity of 16,000 hp. at 800—900 ft. head.

at 15,000 v., single phase, using 6-pole alternators with revolving fields. At the Ritom plant, which ties in with the Amsteg plant, four Pelton wheel units are used, similar to those at Amsteg, under a head of 2700 ft. and a speed of 333⅓ r.p.m. with a total output of 9000 kv.a. These machines are fairly representative of high head Pelton wheel installations in Europe.

Reaction Turbines Are Successful with High Heads

For many years the hydraulic turbine manufacturer had been confronted with the problem of how a reaction turbine might be satisfactorily constructed to operate efficiently under heads of over 300 or 400 ft. It had been found from experience with reaction turbines of ordinary design installed for operation under high heads that a

FIG. 4. OAK GROVE PLANT, USING REACTION TURBINE AT 857 FT. HEAD, ATTRACTS MUCH ATTENTION

considerable loss in quantity was experienced from excessive leakage above and below the turbine runner and a large portion of the water would enter the runner at an incorrect angle as the result of excessive leakage between the top and bottom of the movable guide vanes and the corresponding distributor plates. In order to decrease the turbine losses due to these excessive leakage conditions two fundamental improvements have been made; namely, the provision of labyrinth seals on the runner crown and band and the development of the disk guide vane. With this arrangement and with very close clearances, the amount of leakage will be greatly reduced. Figure 5 shows a turbine runner provided with labyrinth seals and designed to deliver 30,000 hp. under a head of 680 ft. at the speed of 428 r.p.m.

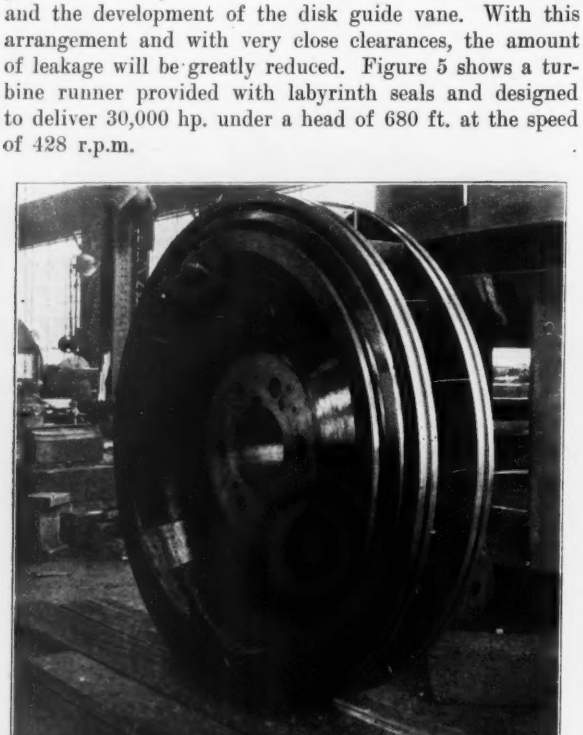


FIG. 5. THIS 30,000-HP. RUNNER, FOR A HEAD OF 680 FT. IS FITTED WITH LABYRINTH SEALS

In connection with the excessive leakage above and below the guide vanes, vanes of the disk type as illustrated in Fig. 3E have been developed. This type of vane differs from the usual guide vane in that a circular disk is cast above and below each vane as an integral part of the casting in order that the leakage clearances between the adjacent vanes will be greatly minimized. With these two improvements in design the efficiencies of high head hydraulic turbines have been appreciably increased, due both to the decrease in quantity lost through leakage and to the increase in effectiveness of the water entering the runner after having passed through the guide vanes.

Rubber Seal Rings Reduce Leakage

In a number of instances seal rings made of rubber have been provided at the top and bottom of the runner in place of labyrinth seals. Turbines equipped with rubber seal rings have been in operation only a few years, but the service rendered during such intervals of time has been satisfactory both from a standpoint of durability and reduced leakage. Rubber seal rings are particularly advantageous where the water flowing through the unit contains an excessive amount of sand or grit. Under these conditions the resilience of the rubber will appreciably increase the life of the seals. Perhaps the highest head reaction turbine ever constructed is the 35,000-hp. turbine installed in the Oak Grove plant of the Portland Railway Light & Power Co. This turbine was designed for operation under a head of 857 ft. at the speed of 514 r.p.m. and is shown in Fig. 6. This turbine has operated with entire satisfaction for more than a year and is equipped with the disk type guide vanes and rubber seals above and below the runner.

In the Big-Creek-San Joaquin project of the Southern California Edison Co., which supplies the 220-kv. lines running 270 mi. to Laguna Bell, 16 hydro-electric plants are tied into the system, using heads varying from 350 ft. to 2400 ft. The Big Creek No. 3 plant, previously described in these columns, at present has three 35,000-hp. reaction turbines running at a head of 760 ft. and a speed of 423 r.p.m., and three more will be installed to give an ultimate capacity of 200,000 hp.

It is only within comparatively recent months that the reaction turbine has been manufactured in Europe for high heads, but these are mostly for shipment to the colonies, where they are employed for heads of 400 to 600 ft. Reaction turbines using horizontal overhung wheels have been built of 3500 hp. at a head of 420 ft. and a speed of 600 r.p.m., for the Herlandsfosen plant in Norway. The English Electric Co.'s 25,000-hp. turbines for the Sorocaba scheme, Brazil, show the influence of American practice. These turbines operate on a head of 600 ft., using electro-hydraulically operated control valves and a governor-operated relief valve of orthodox form.

Natural Features Aid Surge Tank Construction

In most of the high head developments the question of penstock design, surge tanks and control valves for the various pipe lines assumes great importance. They will not be discussed here, however, except to call attention to the interesting way in which natural features of topography are made to aid the construction. For example, the surge tank on the 30,000-ft. tunnel of the Big Creek No. 3 station is cut in the shape of an hour glass, out of solid granite on the mountain side above the station. At Oak Grove, a conical knoll above the power house site was pierced with a tunnel 434 ft. long and 14 ft. in diameter,

from which a 14-ft. shaft rises vertically 103 ft. to the surge tank proper. This is shown at the top of Fig. 4. Penstocks are in most cases made of steel riveted pipe.

As a result of recent improvements, reaction turbines are now being used for the development of hydro-electric energy where in the past only turbines of the impulse type would have been considered. It is believed that, on a basis of these recent improvements, the range in head under which reaction turbines may be satisfactorily operated will be consistently increased as their adaptability to high head operation is successfully demonstrated by actual performance.

Improved Control Methods Increase Efficiency

In case of excessive guide vane leakage at no load, the Oak Grove turbine is controlled within synchronizing speed by throttling the water supply at the casing inlet with a water-motor-operated butterfly valve, fitted with the usual bypass. Complete water-tight control is obtained with a Johnson needle valve at the head of the penstock; this valve can be controlled from the power house, but is arranged so that it can be opened and the penstock filled only at the valve itself.

Much thought is being given to the elimination of the usual belt drive for governors, as the belts may break. Slacking up of a governor belt has a serious effect on the governor. Direct connection is difficult on account of the slight vertical movement of the turbine shaft under varying loads. It may be possible, however, to use 45 deg. spiral gears for driving the governor. This has already been tried out with considerable success in the Pit River No. 3 plant of the Pacific Gas & Electric Co. The governor shaft is made to revolve directly with the turbine shaft at all speeds. Obviously, a successful substitute for belt drive must hold the governor speed proportional to that of the turbine under all conditions. With large units, it may often be necessary, even in case of short circuit, to hold the unit on the system even though it may at such a time be greatly overloaded. A successful electric governor drive should turn the centrifugal element of the governor directly with each revolution of the main shaft, whether the speed is one revolution or above normal. It is reported that the solution of this problem of an electric belt for governors may be expected. Governors are now provided with satisfactory protective and safety appliances and little remains to be done in this direction.

In many instances, oil pressure sets operating on the volume-controlled system are being used in preference to the pressure controlled type. Practice in the later hydro-electric installations is to use individual oil sets for each unit, such a set being shown in Fig. 3G. Each set includes two pumps of full capacity, one being direct connected to a slow speed motor, and the other to a small water wheel, which is used as a standby and for starting.

Automatic plants for high head operation are being successfully used, the automatic features being much the same as for low heads, although such plants are usually of comparatively small size. Usually their operation is controlled from a master float in the forebay.

In practically every installation of recent construction in which the turbine units are of large or medium size, units of the vertical shaft type have been adopted. The principal advantages of the vertical shaft units over those of the horizontal shaft type are: 1. Higher efficiencies due principally to more satisfactory design of draft tube; 2. Better mechanical construction; 3. Less wear on the guide bearings; 4. Lower first cost of equipment.

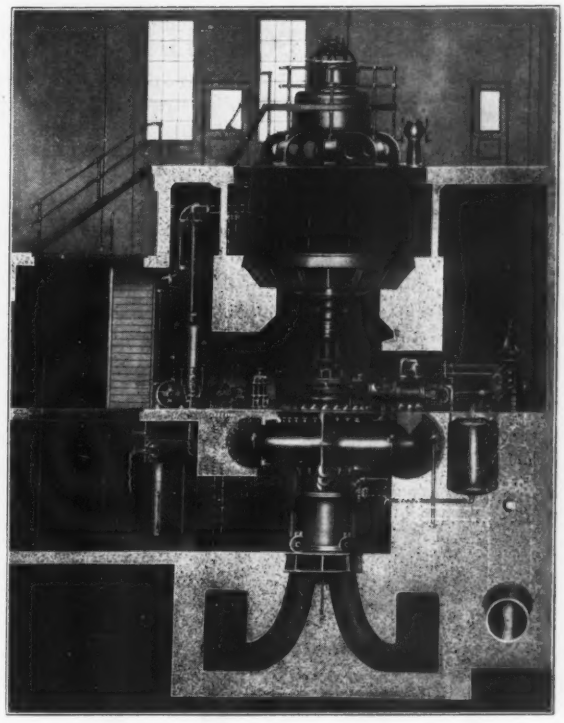


FIG. 6. OAK GROVE 35,000-HP. UNIT HAS RUBBER SEAL RINGS AND DISK TYPE GUIDE VANES

We wish to express our thanks to F. H. Rogers, of the I. P. Morris Dept. of William Cramp & Sons Ship and Engine Building Co., and to Ely C. Hutchinson, of The Pelton Water Wheel Co., for their valuable assistance in furnishing data and photographs incorporated in this article. For permission to reproduce photographs and information from Mr. Hutchinson's recent paper before the Third Annual Hydro-Electric Conference, we wish to thank the Engineers' Club of Philadelphia.

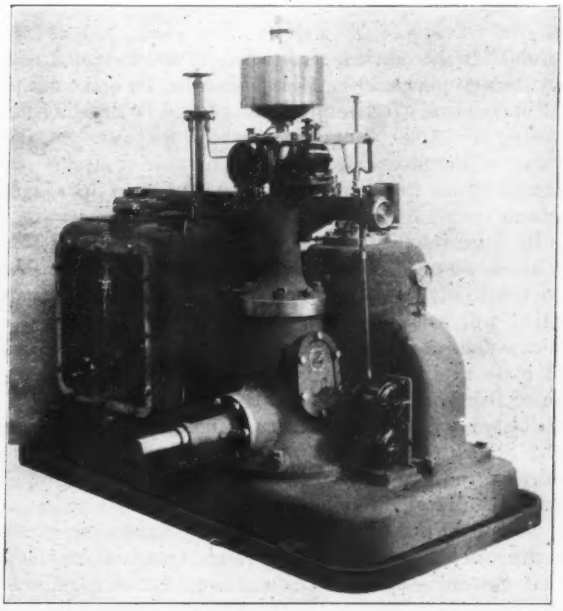


FIG. 7. GOVERNORS ARE SOMETIMES DRIVEN WITH 45 DEG. SPIRAL GEARS. GEAR SHAFT SHOWN IN FRONT

Features of Airless Injection Engines

Reasons for Variation in Brake M. E. P. of Different Types. By H. F. Birnie

ALTHOUGH THE TRUE Diesel engine has been in successful operation for a number of years, the air compression system is cumbersome and is generally the cause of a large percentage of the Diesel operating troubles. In an attempt to attain the performance of the Diesel engine without its disadvantages of low mechanical efficiency and high pressure air compressor troubles, engineers have developed the airless injection engine.

Variation in Mean Effective Pressure

Study of this type discloses a particularly outstanding feature. In comparing different makes of these engines, it is found that the mean effective pressure varies considerably with each type. Ratings of these engines will vary from as low as 40 lb. to as high as 90 lb. brake m.e.p. The brake mean effective pressure is found by dividing the product of 33,000 times the brake horsepower by the product of the piston stroke in feet, number of strokes per minutes of all the cylinders, and piston area in square inches.

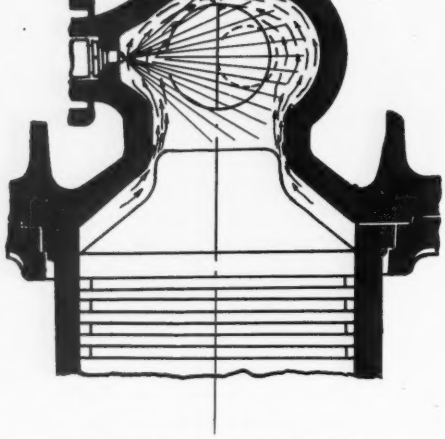


FIG. 1. SHAPE OF COMBUSTION CHAMBER INSURES MAXIMUM TURBULENCE

In order intelligently to determine the causes of this variation, we must consider methods of fuel injection. At this time, only those engines using straight spray atomization will be considered. This is in contrast to those which employ a pre-combustion chamber, a hot bulb, or a hot plate against which the spray impinges. The problem of airless injection, or as it is sometimes called "solid" injection, consists in satisfactory design and application of three principal factors; combustion chamber, fuel pump and spray nozzle. Their successful co-ordination must be a primary consideration.

Although the fuel pump is the primary agent in creating necessary pressure for high spray velocity, the other elements—spray nozzle and combustion chamber—must be so designed that the spray resulting from the high pressure will give the best possible combustion conditions by not only causing extreme atomization, but by creating a movement of air and oil particles known as "turbulence."

Turbulence Necessary for Complete Combustion

Turbulence always exists in the cylinders and is created by air rushing in through the intake valves or ports during the suction or scavenging stroke. It is not only desirable but necessary to obtain the requisite sharpness of ignition. Speed of ignition is exceedingly high and the time required for complete mixing of air and fuel must be reduced to a minimum.

One of the best means of effecting turbulence is proper design of the combustion chamber. In Fig. 1 turbulence is produced by the shape of the top of the piston, which at the top of its stroke projects into the combustion chamber and forms a plug past which air is forced at high speed as the piston rises. In this way, air is circulated around the walls of the chamber without disturbing the "hot core," as shown by the dotted lines. As shown in Fig. 1, the shape of the combustion chamber is spheroidal, although the theory is that a spherical chamber will give the least wall surface exposed to the water jacket and permit of a central core of air heated by compression and cooled as little as possible by contact with the walls. This core is relied on to fire the charge. The change from spherical to spheroidal is rendered necessary by the cooling effect of the incoming charge of fuel, which tends to transfer the central core towards the left as shown by the dotted circle, since, if the chamber were spherical, it would be brought into contact with the water-cooled walls. By making the chamber spheroidal there still remains a good clearance between the hot core and the jacket.

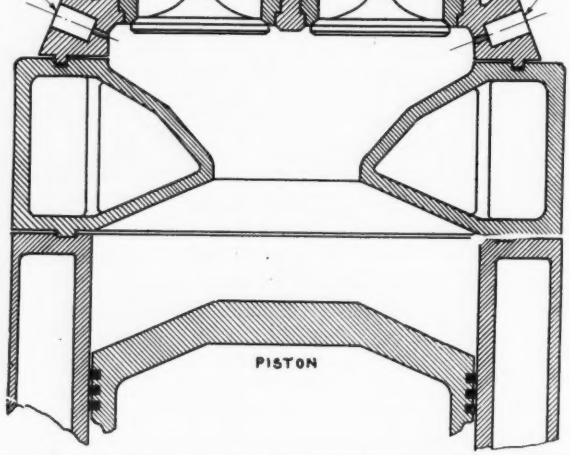


FIG. 2. LOCATION OF VALVES INSURES GOOD SCAVENGING

In Figs. 2 and 3 other designs of combustion chamber for giving induced turbulence are shown. In Fig. 2, this is effected by means of the restricted openings between the cylinder head cavity and the cylinder proper. The exhaust and inlet valves are situated in this chamber insuring good scavenging. Fuel sprays are shown opposite

each other. Figure 3 illustrates a design of combustion chamber used on smaller engines. The cylinder cover has a deep projection and forms with the liner an annular space into which the upper part of the piston enters. When the piston is nearing the end of the stroke, the air is trapped in the ring recess and forced from there into the combustion space through the opening A. Fuel is injected at this instant and thorough mixing of air and fuel insured.

Although there is always a natural turbulent action of air in the cylinders, the term "turbulence" is ordinarily used only when the design provides for directing or increasing this natural air movement.

In general, air turbulence is required when, considering the period of injection as a whole, the fuel is not finely divided and the force of the spray action itself does not cause adequate mixing with air for complete combustion of the amount of oil supplied during this entire period.

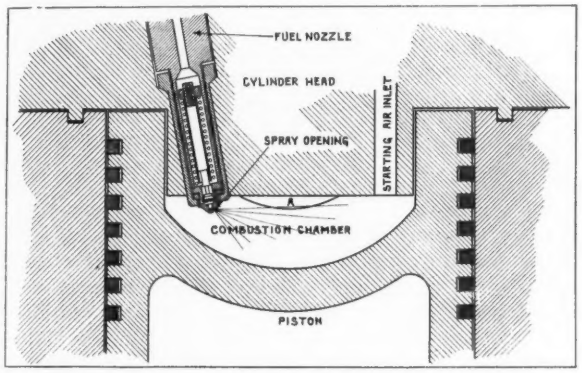


FIG. 3. COMPLETE COMBUSTION EFFECTED WITH MINIMUM AMOUNT OF AIR DUE TO SHAPE OF CHAMBER

Figure 4 is a reproduction of an indicator card taken on an engine giving an indicated m.e.p. of 100 lb. per sq. in. This high pressure is due, in a large measure, to the excellent induced turbulence provided in the design of the combustion chamber and to the high velocity of the fuel injected at the spray nozzle.

High Velocity of Spray Needed for Maximum Power

For the most effective operation of oil engines, it has been found that a spray velocity of about 1000 ft. per sec. is necessary. When using compressed air as the diffusing medium, this velocity is easily attained with medium sized openings in the spray nozzle, but with airless injection much smaller holes must be used. With other conditions constant, the size of these openings should be proportional to the power rating of the cylinder.

Calculation of Approximate Size of Spray Holes

Where the velocity is known and it is desired to calculate the size of the spray holes, the following equation may be used—

$$F = \frac{Q}{V} \qquad (1)$$

where,

F = total area of spray holes in sq. in., Q = amount of fuel discharged, cu. in. per sec., V = velocity, in. per sec.

In order to determine the value of Q, the following data must be known:

Horsepower per cylinder, revolutions per minute of engine, angular motion of crank during injection, fuel consumption per horsepower-hour, type of engine—2 or 4 cycle. Then, assuming 100 hp. per cylinder, 200 r.p.m., 30 deg. angular motion of crank during injection, 0.42 lb. fuel per b.hp.-hr., 4 cycles, 2 spray holes per cylinder and one cylinder, we have the following:

$0.42 \times 100 = 42$ lb. per hr. per cylinder, and $42 \div 60 = 0.7$ lb. per min. per cylinder. Then, since there is one firing for each two revolutions,

$$0.7 \div \frac{200}{2} = 0.007 \text{ lb.}$$

per firing stroke. In 200 revolutions the crank shaft will describe $200 \times 360 = 72{,}000$ deg. per min. or 1200 deg. per sec. Then the time required for an angular motion of 30 deg. will be

$$30 \times \frac{1}{1200} = 0.025 \text{ sec.}$$

Accordingly, the rate of flow through the nozzle openings will be:

$$\frac{1}{1200} \times 0.007 = 0.28 \text{ lb. fuel per sec.}$$

If oil of 29.1 deg. Be. at 60 deg. F. is used, there will be 0.1365 gal. per lb. Then, $0.28 \times 0.1365 \times 231 = 8.85$ cu. in. per sec. which is the value of Q.

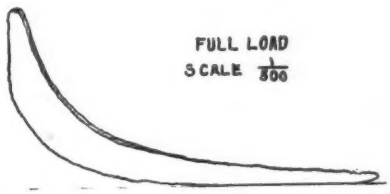


FIG. 4. TURBULENCE AND HIGH SPRAY VELOCITY GIVES M.E.P. OF 100 LB. PER SQ. IN.

Substituting in equation (1), we have

$$F = \frac{8.85}{1000 \times 12} = 0.000{,}738 \text{ sq. in.}$$

total area of nozzle openings, or 0.000,369 sq. in. for each hole. The diameter of each hole is accordingly, 0.021,68 in.

It is also of interest to note how the oil pressure may be calculated. Since the velocity of any fluid may be determined by the well known equation

$$V = C\ 8.02 \sqrt{H}$$

where,

V = velocity in ft. per sec., C = coefficient of discharge (ordinarily assumed 0.60), H = pressure head in ft., then by assuming a velocity of 1000 ft. per sec. and transposing the equation, we have

$$H = \frac{V^2}{23.14} = \frac{250{,}000}{23.14} = 10{,}800 \text{ ft. water head.}$$

Since a height of 2.31 ft. of water is equivalent to a pressure of 1 lb. per sq. in., then 10,800 ft. is equivalent to a pressure of 4675 lb. per sq. in. required at the nozzle. This shows that the pressure in the fuel line determines the spray velocity which in turn is governed by the size of the nozzle openings.

Figure 5 shows the spray tip at the end of the valve. Fuel is conducted to the end of the needle through four grooves on the outside of the needle bushing. As the needle is lifted the fuel passes to the spray tip and is injected

into the combustion chamber through the spray holes. If the velocity remains constant, the openings of the spray nozzle must vary according to the duration of the fuel injection, which means that the shorter the latter the larger the openings must be.

Design of Combustion Chamber and Spray Velocity Affect M. E. P.

It may be seen from the foregoing observations that the design of the combustion chamber directly affects the turbulence which is necessary for complete mixing of air and fuel. Closely linked with this condition is the velocity of the fuel spray. This must be kept uniformly high throughout the entire period of injection or the turbulent action of the air itself will not be sufficient to cause effective combustion. Those engines which have all conditions of design so co-related that maximum turbulence and high

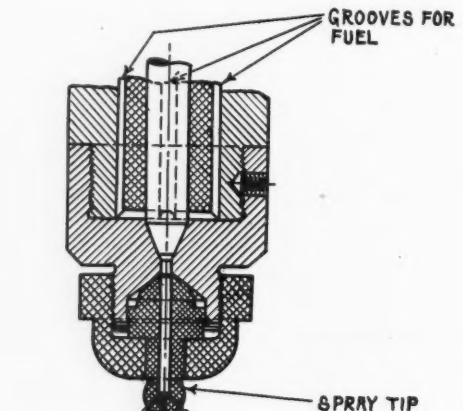


FIG. 5. DESIGN OF SPRAY TIP AND HOLES

spray velocities are assured, are the ones which show the highest mean effective pressure.

As previously stated the fuel pump is but a means to an end and so long as a high spray velocity is provided, it doesn't matter much what sort of pump is used. Some pumps, however, are more effective than others, in providing a high velocity at every instant of the injection period and, of course, the best results will be obtained with these types of pumps. In a subsequent issue methods of fuel injection will be discussed in detail.

New Method of Generating High Pressure Steam

By Carl Commentz

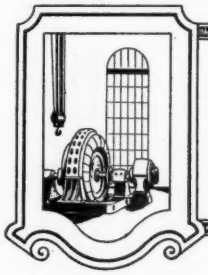
DEVELOPMENT OF the internal combustion engine has created a great amount of interest in the more economical production and use of steam. It has been realized by those interested in the steam side of the problem that one of the most promising ways of obtaining greater economy was to put into practice a considerable rise of pressure. The result has been that a number of boilers have been developed for pressures not only up to 1400 lb. per sq. in., but even up to 3500 lb. per sq. in. Until just recently the Atmos system of steam generation and the Benson boiler have been the best known among these new types. The difficulty of generating steam at such pressures lies in the fact that the parts of the boiler in which the water is evaporated are also exposed externally to the heat of the combustion gases and they soon become covered with scale even when distilled feed water is used. Any formation of scale prevents heat transmission and leads to the destruction of the boiler tubes exposed to the heat of the furnace.

Recently there has been developed a new and promising way of generating high pressure steam, which avoids the drawback previously mentioned. This was made public on March 19th, by Prof. Loeffler in Wien and at the same time he was able to show a successful installation. This experimental plant operates under a pressure of 1400 lb. per sq. in.

This new system deviates from the usual method of evaporating water which is by applying external heat to a boiler. It consists essentially of an evaporator, which is independent of the combustion chamber, and a superheater which is located in the combustion chamber. This superheater contains only steam and in it the steam is raised to such a degree of superheat that when passed through the evaporator it evaporates the water. The superheated steam naturally loses part of its heat, but this is regenerated in the superheater and the steam finally leaves the steam generating plant with a pressure of 1400 lb. and with a temperature of from 750 to 940 deg. F. The most important part of the system naturally is the superheater which is made of Siemens-Martin steel which is ordinarily used for superheater construction. Steam is forced through the tube system of the superheater by means of special pumps and since only dry steam is circulating in the superheater no scale is formed. The superheater tubes are small in diameter, therefore the dangers of explosion are minimized. The evaporator is exposed to the full steam pressure, therefore its temperature is rather low as compared with that of direct fired boiler.

When starting the plant, auxiliary steam generated in a regular boiler must first be led into the plant; this steam may be taken either from some foreign steam plant or from an auxiliary boiler with a pressure of about 28 lb. per sq. in. At the plant in Floridsdorf, foreign steam with a pressure of 170 lb. per sq. in. was used and the time necessary to increase the steam pressure up to 1400 lb. proved to be only about 1 hr. or much less than the time required to bring a direct fired boiler up to its pressure. Scale may be formed in the evaporator without objection and when it does form it is an advantage, for it serves as a medium of heat insulation. The evaporator may be located near the steam engine and the steam generation may be automatically regulated from the steam engine.

Difficulties which were first experienced in the use of high pressure steam in engines have now been surmounted and turbines as well as reciprocating engines may be used with high pressure steam. Under certain circumstances the fuel consumption of steam plants working with 1400 lb. pressure will be only half of that of normal steam plants. Such savings are possible especially if these power plants work in conjunction with steam heating plants and railway engines working with exhaust steam. It is said that this new Loeffler system of generating high pressure steam may be applied favorably not only to large power plants but also to small and medium sized plants.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Exciter Practice in Electric Power Stations

ALTHOUGH A SMALL PIECE OF EQUIPMENT IN ITSELF, FAILURE OF AN EXCITER MAY MEAN THE LOSS OF THE ENTIRE STATION OUTPUT. BY H. M. RANKIN*

IN THE DESIGN of an electric power station the question of the proper excitation system is one involving many factors and is determined principally from the standpoint of reliability, rather than cost. Except in the case of exciters directly connected to the shaft of very low speed generators, the cost of the exciter itself is a relatively small part of the total development. On the other hand, failure of a small exciter may mean the loss of the output of a large generator, possibly the loss of the entire output of the station.

In the early days of the electrical art, when direct current only was involved, the storage battery came to be regarded as the outstanding source of reliable power and when alternating current came into use, the various Edison companies turned to the battery, naturally, as the best reserve source of excitation. This necessitated exciters operated in parallel with the battery floating on the exciter buses and, in many instances, power for station auxiliaries and emergency lighting was taken from the same source.

The development of automatic voltage regulators introduced a new factor, as with these devices the voltage of the excitation bus no longer remained constant and, if batteries were used, it required the use of a booster exciter connected between the constant voltage exciter bus and the excitation bus to which the alternator fields were connected. The regulator then operated on the field of the booster exciter.

In the accompanying table are listed the excitation systems of some of the larger stations in the United States and Canada. It will be noted that the use of exciters operated in parallel with the storage battery reserve is by no means obsolete, as two of the most modern stations of large Edison Companies, Hudson Avenue, Brooklyn and Weymouth, Boston, are so equipped. That there is, however, even among the large Edison companies, a trend toward what may be termed the "unit system" in which individual exciters are used for each main generator, is indicated by the tabulation for the Hell Gate Station in New York and Calumet Station in Chicago.

Other stations, both steam and hydro-electric, using the unit system, are also enumerated. In one case, Tallulah Falls, the original installation was for parallel operation of exciters and, later, provision was made for unit operation if desired.

The two chief advantages of this system are its simplicity and the fact that exciter trouble involves only one main generator, instead of jeopardizing the entire station.

*General Electric Co.

When the excitation is to be taken from a common exciter bus, it has frequently been the practice to employ a small number of relatively large exciters, driven by prime movers, thereby economizing in space and obtaining the

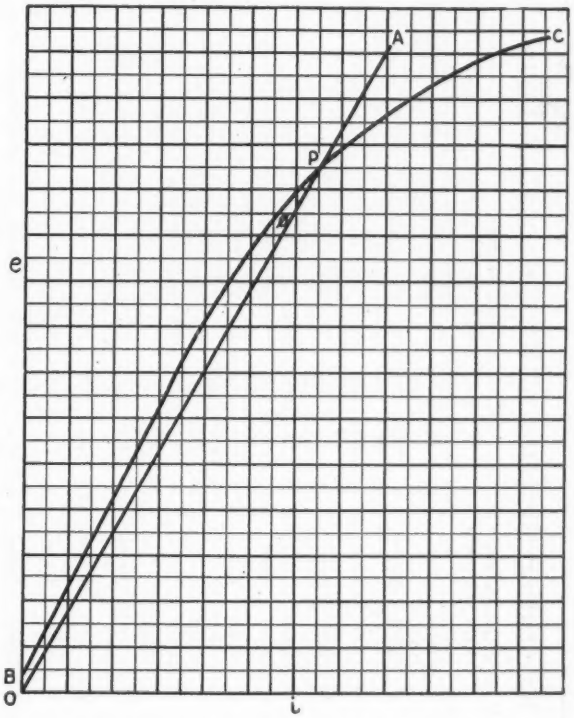


FIG. 1. THE ANGLE Ø BETWEEN THE LINE OA AND THE CURVE BC IS A MEASURE OF THE EXCITER'S STABILITY

benefit of the better efficiency of the larger machines. In the case of hydro-electric plants with water wheel-driven exciters, this will also result in lower investment and installation charges and increased reliability, due to larger exciter water wheels and penstocks which are not so likely to become clogged with ice and trash as are those of smaller size.

Use of combined water wheel and motor drive, or steam turbine and motor drive, is also quite common and very reliable because, in case of failure of either source of power, the other will assume the load. In the case of steam stations, dual drive is of use as a means of obtaining a proper heat balance, as the governor of the exciter turbine may be adjusted to assume any part of the load desired.

Excitation Systems of Representative Power Stations

STATION	COMPANY	MAIN GENERATORS No.	Kv. a. Rating	Steam or Hydro	EXCITERS No.	K W.	Volts	Type of Drive	Voltage Regulator	EXCITATION SYSTEM
Hell Gate	United Electric Lt. & Pr. Co.	3	35000	Steam	6	150	250	Main Gen'r Shaft	None	Individual operation of main exciters. Main exc'rs take their excitation from aux. exc. which may operate separately or with storage battery.
		3	40000		4	10	250	Aux. Exc'r Dual Drive.		
Hudson Ave.	Brooklyn Edison Co	2	62500	Steam	2	300	250	Main Gen'r Shaft	None	Exciter bus with storage battery reserve.
					2	600	250	Motor		
Weymouth	Boston Edison Co	2	37500	Steam	2	200	250	Motor	None	Exciter bus with storage battery reserve.
					1	250	250	Motor		
Calumet	Commonwealth Edison Co	5	35300	Steam	2	160	230	Main Gen'r Shaft	None	Unit system. Two 200 KW motor driven exciters and one 1500 amp.-hour storage battery on reserve excitation bus.
					4	140	230			
		1	43500		2	200	230	Motor		
Windsor, W. Va.	American Gas & Electric Co	6	30000	Steam	6	210	250	Main Gen'r Shaft	For each unit & one spare	Unit system. Spare exciter may be substituted for any direct connected exciter.
					1	150	250	Motor		
Northeast	Kansas City Power & Light Co.	3	25000	Steam	3	200	250	Main Gen'r Shaft	For each unit & one spare	Unit system. Spare exciter may be substituted for any direct connected exciter.
					1	175	250			
		1	33333		1	200	250	Turbine		
Amsterdam	Adirondack Power & Light Corp. (Initial Installation.)	2	18750	Steam	2	100	250	Main Gen'r Shaft	For each unit & one spare	Unit system. Spare exciter may be substituted for any direct connected exciter.
					1	150				
		1	37500		1	170	250	Motor		
Keokuk	Mississippi River Power Co	15	9000	Hydro	15	100	250	Motor	For each unit	Unit system. Exciter motors take power from two auxiliary A. C. generators having direct connected exciters and regulators.
Cedars	Cedar Rapids Pr. & Mfg. Co.	18	10000	Hydro	18	150	250	Motor	For each unit	Unit system similar to Keokuk. Storage battery connection is provided for emergency excitation.
Mitchell Dam	Alabama Power Co	3	20000	Hydro	3	190	250	Main Gen'r Shaft	For each unit	Unit system. Spare exciter may be substituted for any direct connected exciter.
					1		250	Motor		
Pit River No. 1.	Pacific Gas & Elec. Co	2	35000	Hydro	2	225	250	Main Gen'r Shaft	For each unit	Unit system. Spare exciter may be substituted for any direct connected exciter.
					1	225	250	Motor		
Pit River No. 3.	Pacific Gas & Elec. Co	3	27000	Hydro	3	160	250	Main Gen'r Shaft	For each unit & spare	Unit system. Spare exciter may be substituted for any direct connected exciter.
					1	160	250	Motor		
Queenston	Hydro-Elec. Pr. Com. of Ontario.	5	45000	Hydro	5	150	250	Main Gen'r Shaft	For each unit	Unit system.
					1	150	250	Motor		
Big Creek No. 1.	So. California Edison Co	3	17500	Hydro	1	150	...	Motor & Water Wheel	Regulator	Exciter bus. Each exciter is capable of exciting two main generators.
					1	150	...	Motor	Operates on agitator set	
					1			Agitator M-G set for excitation of main exciters		
Tallulah Falls	Georgia Railway & Power Co.	6	10000	Hydro	6	100	250	Main Gen'r Shaft	Two	Exciters may be operated in parallel or individually with generators. Each exciter is capable of furnishing excitation for two generators.
Tugaloo	Georgia Railway & Power Co.	4	12000	Hydro	4	100	250	Main Gen'r Shaft	Two	Unit system. Spare exciter may be substituted for any direct connected exciter.
					1	100	250	Water Wheel		
Fishing Creek	Southern Power Co	5	7500	Hydro	5	95	250	Main Gen'r Shaft	None	Unit system.
Long Lake	Washington Water Power Co.	4	17500	Hydro	4	220	250	Main Gen'r Shaft	For each unit	Unit system.
White River	Puget Sound Pr. & Lt. Co.	2	16300	Hydro	1	340	250	Motor & Water Wheel	One	Exciter bus.
		2	20000	Hydro	1	340	250	Water Wheel		
Cabot	Turner's Falls Power Co	6	7500	Hydro	4	95	250	Main Gen'r Shaft	For each unit	Unit system. Spare exciter may be substituted for any direct connected exciter.
					2	145	250	Main Gen'r Shaft		
					1	100	250	Motor		
Sherman Island	International Paper Co	4	9000	Hydro	4	114	250	Main Gen'r Shaft	For each unit & spare	Unit system. Spare exciter may be substituted for any direct connected exciter.
					1	115	250	Motor		
Caribou	Great Western Power Co	3	22223	Hydro	2	600	250	Motor & Water Wheel	Two	Two exciter busses. Each exciter is capable of exciting three generators.
Great Falls	Montana Power Co	6	10000	Hydro	2	500	240	Water Wheel	For each exciter	Each exciter capable of furnishing excitation for all generators.
Thompson Falls	Montana Power Co	6	6250	Hydro	2	500	240	Water Wheel	For each exciter	Each exciter capable of furnishing excitation for all generators.
Narrows	Tallassee Power Co	2	18000	Hydro	2	72	250	Main Gen'r Shaft	None	Unit system. No alternator field rheostats used except for unit consisting of 1 18000 KVA 36 cycle generator on same shaft with 1 31250 KVA 60 cycle generator as same may be used as frequency changer. Alternators operate always at practically full load.
		1	18000	Hydro	1	300	250	Main Gen'r Shaft		
		1	31250							
		1	23160	Hydro	1	175	250	Main Gen'r Shaft		
					1	100	250	Motor		

Exciters directly connected to the shafts of the main generators are in general the simplest and most economical. This arrangement gives the exciter the benefit of the most efficient and best regulated prime mover in the station, and the added investment to take care of the additional water wheel or turbine capacity due to the exciter is small. Economy of space is another item in its favor, especially in the case of vertical water wheel-driven generators, as the space required for the direct-connected exciter is in general less than that required for dismantling the main unit.

There are, however, limitations applying to the use of direct-connected exciters. If the speed is extremely low, the exciter becomes exceedingly large and costly and, in that case, higher speed exciters belted to the generator shaft, or driven by some other source, may be more economical. On the other hand, in the case of steam turbine-driven generators at speed above 1800 r.p.m., commutation difficulties may be encountered unless great care is taken in the design of the exciter.

Motor-driven exciters are often used and, as the speed may be high, their cost will be correspondingly low. There must, of necessity, be some reliable source of supply for the motors, usually a house generator, separate from the main system, with an additional source of supply from the main system through station auxiliary transformers.

Either of the last two schemes lends itself particularly well to the unit system of excitation.

Spare Exciter Capacity

In the past there has been a wide variation in the spare exciter capacity provided, ranging from zero to 100 per cent spare capacity. Considering the fact that the present day exciter is an extremely reliable piece of equipment, 100 per cent spare capacity seems far too much, though unquestionably some spare capacity should be provided. In the case of exciters direct-connected to high-speed turbine generators, the additional capacity does not cost much, but the switching equipment necessary to provide a flexible arrangement may add appreciably to the expense. In a number of modern stations using the unit system of excitation, the main generators have been equipped with direct-connected exciters, each capable of furnishing only the excitation for its own generator, and a spare exciter driven either by a motor or the prime mover, has been provided capable of exciting the largest generator in the station. Means are provided for substituting this spare exciter for any of the direct-connected exciters in the station, but not for operating any exciters in parallel.

Apparently, this has been a satisfactory arrangement, as the number of installations of this nature is constantly increasing.

Automatic Voltage Regulator

Use of automatic voltage regulators is highly desirable for a number of reasons, some of which are listed as follows:

Constant bus voltage may be maintained or, by the use of line drop compensators, line drop in a main feeder or transmission line may be compensated to meet load conditions.

Cross current between generators may be kept to a minimum, or eliminated.

Stability of the excitation system is increased. This point will be covered in more detail under the head of "Stability of Exciters."

Stability of the power system, as a whole, meaning the ability of various generators or generating stations to stay in step during system trouble, or pull back into step after system troubles, is increased.

With exciters operated in parallel, only one regulator having sufficient contacts to take care of the fields of all the exciters is required.

In the unit system, an individual regulator is desirable for each unit and either a spare regulator for use with the spare exciter, or else means of transferring the contacts of each regulator to the spare exciter. This system is more flexible and permits the automatic holding of different voltages on different sections of the main busses, if desirable, to take care of various types of load.

Exciters, to be suitable for operation with a voltage regulator, are usually made to operate at low saturation,

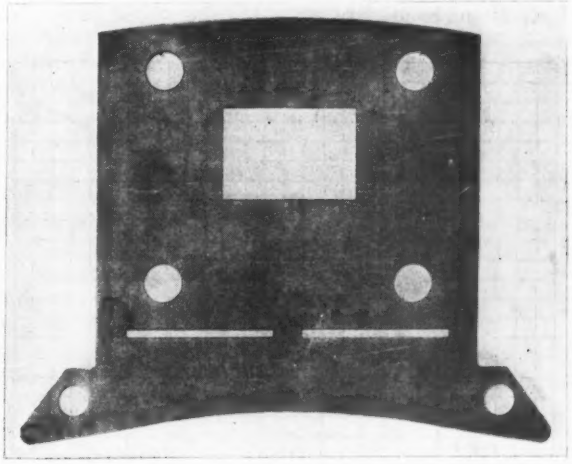


FIG. 2. IN A NUMBER OF CASES THE SATURATION CURVE OF AN EXCITER HAS BEEN CHANGED BY SLOTTING THE FIELD POLES IN THIS MANNER

i.e., on the straight part of the saturation curve, therefore they do not have a wide range of stable operation under manual control. This point will be taken up in more detail under the subject of "Stability."

Main Generator Field Rheostat

When the exciters are operated in parallel, the use of rheostats in the fields of the main generators to take care of the requirements and characteristics of the various machines is imperative.

In the unit system, under normal operation, with automatic voltage regulators or with exciters designed for stable operation with manual control, the generator field rheostat is not required. If, however, normal operation is with voltage regulators and exciters designed for such operation, the generator field rheostats will probably be desirable to take care of the possible requirement of temporary operation without the regulator. In this case, sufficient resistance would be cut into the generator field to bring the exciter voltage up into a range of stable operation. It is possible in many cases to design an exciter which will operate satisfactorily with a regulator and also be stable for manual control over a considerable range, but such design results in a larger and more expensive machine, as the field ampere-turns must be considerably increased over the amount required by an exciter of normal design.

Stability of Exciters

This subject has been thoroughly covered by R. E. Doherty in his paper, "Exciter Instability" (Trans. A. I. E. E., Vol. 41), but it may be well to review briefly the points brought up.

Exciter instability may demonstrate itself in the following manner:

"1. Large change in voltage for small changes in load.

"2. Creeping of voltage up or down without apparent cause.

"3. Temporary removal, partial or total, or even reversal of the excitation accompanying short circuit of the alternator.

"4. Slow oscillation or possible reversal of excitation following a sudden readjustment of either the shunt field or alternator field rheostat."

Stability of an exciter depends upon the ability under all conditions to produce across the shunt field terminals

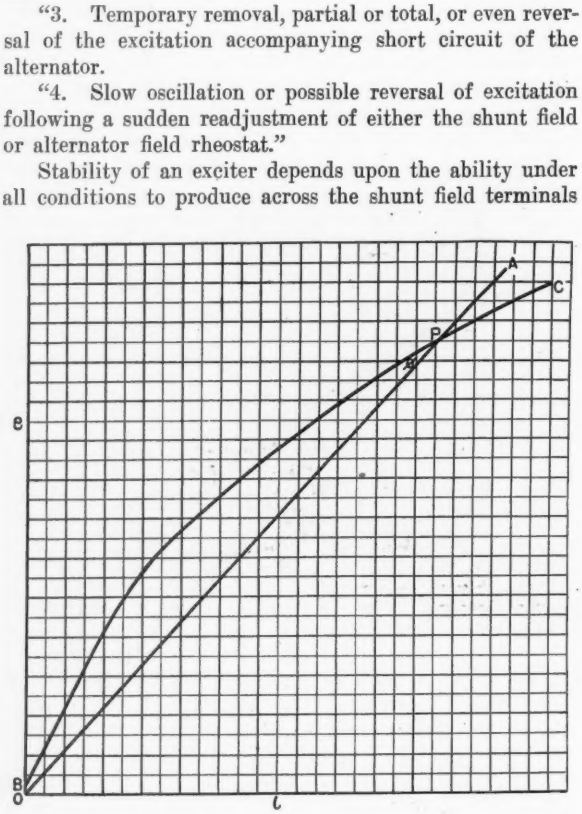


FIG. 3. SLOTTING THE FIELD POLES AS SHOWN IN FIG. 2 PRODUCES A BEND IN THE SATURATION CURVE BELOW THE OPERATING RANGE

a voltage equal to the IR drop in its shunt field circuit. Referring to Fig. 1, if OA represents the IR drop in the shunt field circuit and BC the saturation curve, then the point, P, of intersection of OA with BC is the operating point and the angle ϕ, between OA and BC, is a measure of its stability.

If the angle between the line, OA, and the curve, BC, is too small, then voltage creeping may result from several causes, as follows:

1. Slight momentary changes in speed will shift the operating point, P, one way or the other, depending upon whether the speed increases or decreases, and if, for example, a momentary decrease in speed causes the straight part of the saturation curve practically to coincide with the line representing the IR drop in the field, then the voltage may creep down still farther since, at all points of coincidence of the two lines, the condition holds that the exciter voltage is equal to the IR drop in the field.

2. Voltage creeping in a similar manner may be caused by rising temperature increasing the resistance of the shunt field and, therefore, the slope of the IR line, but not affecting the saturation curve. This would shift the operating point, P, downward.

3. Slight fluctuations in exciter voltage, which means that a local hysteresis loop is being repeatedly traversed, may affect the shape of the saturation curve and eliminate, or seriously reduce, the residual magnetism of the exciter field, again resulting in a downward shift of the operating point, P.

Obviously, the remedy for voltage creeping is to increase the angle ϕ (Fig. 1) between the line OA and the curve BC by changing the shape of the saturation curve. This has been accomplished in a number of instances where manual control was desired, by slotting the field poles, as shown by Fig. 2, thereby introducing an area of reduced cross section which saturates at low values of field current and produces a bend in the saturation curve at a value below the operating range, as shown by Fig. 3.

This, of course, increases the amount of field ampereturns required to force the field flux across the air gaps resulting from slotting the poles, and means a somewhat larger and more expensive machine.

4. Excessive series field strength will cause trouble as, at the lower operating voltages, the series field will predominate and the exciter will act like a series generator. The remedy is, of course, a properly proportioned series field winding.

Oscillation, or reversal of exciter voltage, may be occasioned:

1. By sudden change in the circuit constants, as by sudden large change in setting of either the exciter field or alternator field rheostats, under the condition that operation is on the straight part of the saturation curve, combined with either of two other conditions. These conditions are: Relatively large drop in the exciter armature due either to large demagnetizing component of armature reaction, or large ohmic resistance in the armature circuit between the points to which the terminals of the shunt field are connected. Under the above conditions, a sudden change in rheostat setting resulting in a sudden increase or decrease in load on the exciter means that a different voltage is at once impressed across the exciter field and, if this voltage is less than the IR drop, the voltage may build down to zero, or even reverse and build up again in the opposite direction. This may be avoided on manually controlled exciters by careful proportioning of the resistance steps in exciter field rheostats and careful operation.

2. By transients due to short circuit of the alternator armature providing the exciter is operating on the straight part of the saturation curve and the alternator transient is of greater duration than the exciter transient. Short circuit of the alternator forces a large proportion of the alternator field flux to go through the air gap instead of through the armature iron, therefore resulting in an increased alternator field current to maintain the flux through the higher reluctance of this path. In other words, the load on the exciter is increased.

Increased load on the exciter means a drop in the voltage impressed across the exciter shunt field. This, in turn, means a reduction in exciter field current and therefore a further reduction in exciter voltage and, provided the load is maintained, the exciter voltage will go to zero. Therefore, if the transient of the alternator field is longer than that of the exciter, the load will be maintained and current will still flow in the exciter armature when the ex-

citer flux has reached zero. This means that the IR drop in the armature is now being supplied externally; i.e., from the alternator field. The polarity of the exciter is thus reversed and it will build up in the opposite direction.

Two means are available to meet this situation; viz., the series field on the exciter and the use of an automatic voltage regulator operating on the exciter shunt field. The series field minimizes the voltage drop in the exciter; i.e., the drop in the voltage impressed across the exciter shunt field, and therefore eliminates the tendency toward a further reduction of exciter voltage. The voltage regulator, by instantly decreasing the resistance of the shunt field circuit, thereby decreasing the slope of the IR line, adjusts the exciter for a greater load condition.

Resistance in the alternator field circuit also increases stability by shortening the length of the field transient and increasing the length of the exciter transient. If sufficient resistance is present so that the exciter is operating above the knee of the saturation curve, stability is further increased by saturation.

Conclusions may be deduced as follows: If voltage regulators are normally used, the combination of compound-wound exciters with voltage regulators will give excellent stability, even if no alternator field rheostat is used; however, to take care of manual operation at times when the regulator may not be in use, the alternator field rheostat is advisable.

If no voltage regulator is to be used, some such design as the slotted poles must be resorted to in order to make the exciter stable over the operating range, and series field is desirable as a guard against a reversal under conditions of short circuit on the system.

An exception to the foregoing would be a station such as the Narrows Station of the Tallassee Power Co., where the alternators always operate at full load and, consequently, the exciters are always operating with a considerable degree of saturation.

Reversal of Alternator Field Current

It is possible in some cases to obtain momentary reversal of current through the alternator field and exciter armature circuit, even though the exciter voltage is not reversed, which may possibly cause the incorrect operation of reversal-current relays on exciter circuits. Assume that a short circuit occurs on the a.c. system near a generating station which lowers the voltage on that station and persists until the flux in the generators has materially decreased. If this generating station is interconnected with a system such that voltage is immediately restored across the generator terminals when the short circuit is suddenly removed, the voltage across the terminals of the generators will thus be greater than that which corresponds to the magnetic flux existing in them at that instant. The generators will, therefore, draw a magnetizing current from the system which will produce a flux in the armature corresponding to the restored armature voltage. As the alternator field is short-circuited through the exciter armature, the amount of flux in the field poles cannot change instantly; therefore, if the armature flux due to the restored voltage exceeds the flux which was present in the field due to the field excitation, the field current may not only go to zero, but may actually reverse momentarily. The time of such reversal, as shown by tests recently made, is of the order of half a second. The amount of reversal will, of course, depend upon the magnitude of the voltage restored across the alternator terminals when the short circuit is cleared, and the magnitude of the flux existing in the generator armature at that time, but may exceed in value normal field current.

Summary

The present tendency in excitation systems seems to be toward the use of exciters directly connected to the main generators and each capable of exciting one generator. Spare exciter capacity is provided by means of one, or possibly two exciters, either driven by prime movers or motor-driven from house generators serving station auxiliaries, or with duplex drive, and capable of exciting the largest generator in the station. The exciters are not operated in parallel, but an auxiliary excitation bus is provided, which is energized by the spare exciter and to which the field of any generator may be connected. Individual voltage regulators are preferably used for each unit.

When speed conditions are such that direct-connected exciters are impracticable, motor-driven exciters have been successfully used employing the unit system described above, provided a reliable source of power is furnished for the exciter motors.

In hydro-electric plants where there is danger of trouble from ice or trash in the exciter water wheels or pen-stocks and in steam plants where heat balance conditions govern, duplex drive will be found satisfactory and reliable.

For comparatively small slow-speed developments, exciters belted to the shafts of the main generator will, in general, be found economical.

Conditions of stability point toward the use of compound-wound exciters and the use of alternator field rheostats unless automatic voltage regulators are always in service.

If exciters must be suitable for manual operation over a considerable voltage range, special design should be resorted to in order to insure a definite stable operating point for all voltages within the required limits.

Electricity Production in the United States for the first quarter of 1925 totaled 15.9 billion kilowatt-hours. This was 6 per cent greater than the output for the same period in 1924. More electricity was produced in March at public utility power plants by the use of water power than ever before. The output by the use of water power in March of this year was the same as the output by the use of fuels in March, 1921. This coincidence indicates in a general way the rapid growth in the production and use of electricity during recent years as the output by the use of fuels averages about twice the output by the use of water power.

Production of electricity by the use of water power in the first quarter of this year was about 11 per cent greater than last year. This increase is due partly to better water supply and partly to the increase in capacity of water power plants.

The average daily production of electricity for each month in this year by public-utility power plants and the proportion produced by water power were as follows: January, 179,700,000 kw. hr.—31 per cent; February, 177,900,000 kw. hr.—35 per cent; and March, 173,000,000 kw. hr.—38 per cent. The gradual reduction in the production rate is due to the usual seasonal decline. The preceding figures are from a report just issued by the U. S. Department of the Interior.

High Voltage Transmission Develops Rapidly

EXPERIENCE WITH SEVERAL RECENT 220-KV. INSTALLATIONS SHOWS DESIRABILITY OF THE HIGHER VOLTAGES. DIRECT CURRENT AND UNDERGROUND SYSTEMS ARE POSSIBILITIES

PROGRESS IN the development of electric power transmission systems has been extremely rapid during recent years and our idea of a high tension line today is somewhat different from our idea of a line 10 yr. ago.

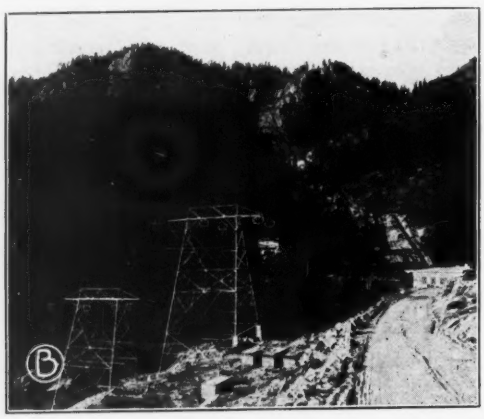


FIG. 1. TOWERS OF THIS TYPE SUPPORT THE 220-KV. BIG CREEK LINE

While the majority of the existing lines in this country were installed for 44 to 88 kv., common practice since about 1919 has been to use 110 kv. or 132 kv., while the most important development of the last two years is probably the 220-kv. line of the Southern California Edison Co. from Big Creek to Laguna Bell and the 220-kv. lines of the Pacific Gas & Electric Co. installed in 1921. A third company, the Pennsylvania Power & Light Co., has purchased equipment and is now working on a 220-kv. installation.

Some interesting transmission systems in Japan are expected to develop within the next few years a total capacity of about 1,000,000 kv.a. Steam and hydro-electric stations are interconnected, some of the transmission lines of the Daido Electric Power Co. being operated at 154 kv. Lines are sectionalized and feeders of 50 and 60 kv. are employed. Oil circuit breakers with rupturing capacities of 4300 amp. for 154 kv. service are used. The synchronous phase modifiers are 3-phase, 60-cycle units of 25,000-kv.a. capacity at zero per cent leading power factor and 17,500 kv.a. at zero per cent lagging power factor. In general, this practice follows closely American ideas. In Australia 132 kv. has been selected as the voltage for the transmission scheme for the state of Victoria.

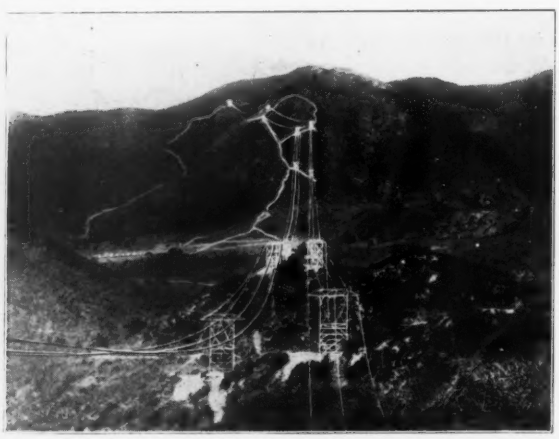


FIG. 2. SECTION OF 150-KV. TRANSMISSION LINE OF PACIFIC LIGHT & POWER CO.

The Big Creek line, a view of which appears in Fig. 1 of the Southern California Edison Co. is approximately 270 mi. long with a total connected capacity of 225,000 kv.a. The Cottonwood-Vaca-Dixon line of the Pacific Gas & Electric Co. has at present a capacity of 254,000 kv.a. The 132 kv. lines of the Idaho Power Co. have been in use since 1914, but in general the trend to the higher voltages is comparatively recent.

The whole question of the employment of high transmission voltages is a part of the interconnection problem. It is probable that 220 kv. will be as high a voltage as will be necessary in this country, since the interconnection systems that are being worked out will probably not require individual systems longer than 500 mi.

In a paper delivered before the A.I.E.E. in February, 1924, Percy H. Thomas worked out the characteristics of a 500-mi. superpower transmission line, working at voltages of from 220 to 245 kv. and delivering regularly 400,000 kw.

To show further what may be done along lines of superpower transmission and interconnection, Mr. Thomas, in another paper, outlined a new type of high-tension network. The central idea of this paper is the superposition of a high tension network of single circuit lines over a large area for the purpose of supplying a medium in which current may flow in any general direction. If such a network is designed favorably, the charging current may largely neutralize the lagging component of the load.

HIGH VOLTAGE DIRECT CURRENT TRANSMISSION IS A POSSIBILITY

In any consideration of interconnection involving long distance transmission of electric energy, the question of providing synchronous apparatus for securing stability is an important one and one that often proves costly. This brings up the question of direct-current transmission, which would entirely eliminate inductive and capacity effects and do away with the necessity of providing automatic synchronous apparatus.

As a means of converting high tension alternating current to direct current, the use of the modern thermionic tube has been suggested and it is possible that the operation of the future long transmission line will be intimately associated with vacuum tube apparatus. The "Transverter" developed in England is of special interest in this connection. This apparatus, as installed at the British Empire Exposition at Wembley, converted direct current at 100,000 v. to alternating current at 3000 v. It may, however, be designed for transformation in any direction. In Europe, the Thury system of direct current transmission has been used for a number of years and has given satisfactory service. Line voltages of approximately 100 kv. are in use with the Thury system and a transmission distance of 112 mi. (Montier-Lyons) has been reached. It is highly improbable that this system will be developed to

a much greater extent than it now is, although there is a possibility of increasing the voltage, but that direct current will ultimately replace alternating current for high voltage transmission purposes is extremely probable.

Results with Underground Lines Are Encouraging

Recent experiments with the Pirelli 132-kv. cable for underground lines in Italy show encouraging results. In America, in keeping with the tendency to go to higher voltages on overhead lines, there is a corresponding tendency to increase the voltage on underground cable systems. The Cleveland Electric Illuminating Co. is now operating successfully 66-kv. underground cables consisting of single conductor, paper covered cables with lead sheath. The manufacturers have been experimenting with 110 and 132-kv. cables, although no installations at these high voltages have yet been made. The Adirondack Power & Light Corp. has been operating an experimental 110-kv. cable near Albany for some time.

In connection with the development of a number of extremely high voltage testing sets there has been some mention lately of the possibility of a million volt transmission line. It has been shown that the conductor for a one million volt transmission line would have to be approximately 8 in. in diameter in order to reduce the corona losses. While this is only one phase of the problem, it indicates to some extent the magnitude of such an undertaking. Experimental work, however, is going on and if at some time in the future we discover the one million volt transmission line to be a necessity, the engineer will find a way to build it and operate it.

Frequencies other than 60-cycle are so seldom used in this country that little need be said about them. European engineers, by using a frequency of 50 cycles, are able to design their larger machines to run at 3000 r.p.m., which they claim is an advantage, and which seem to be successful. The American designer, in the larger unit, is limited to 1800 r.p.m. to get 60 cycles, and unless he splits it up into smaller units he cannot make the step from 1800 to 3600 r.p.m. European engineers also claim that their use of 3000-r.p.m. machines enables them to obtain 60 to 70 per cent more work from a pound of material than we do.

Good Results with 220-kv. Lines Create Confidence

Much confidence in extremely high-voltage transmission has developed from the results obtained on the 220 kv. systems put in operation during 1923-1924 by the Southern California Edison Co. and by the Pacific Gas & Electric Co. The lines from Big Creek No. 1 plant through Big Creek No. 3 to Eagle Rock are 243 mi. long. Taps to Laguna Bell start about 3 mi. from Eagle Rock and are 26 mi. long. From 1913 to 1923, the line from Big Creek to Eagle Rock was 150 kv., but since May, 1923, has operated at 220 kv.

On account of the increase in the legal minimum clearance from conductor to ground, it was necessary, when reconstructing for 220 kv., to install 5, 10 or 15-ft. extensions under 2150 towers out of 3340. Most of this work was done while the lines were energized. Conductors on the Big Creek-Eagle Rock line are of 605,000-c.m. aluminum with 78,500-c.m. steel core. Insulators have 12 units in a suspension string and 13 units in each 2 parallel dead end strings. Lines to Laguna Bell, designed for 220 kv., have conductors of 666,600-c.m. aluminum with 85,400-c.m. steel core. Insulators on the latter line have 13 units in a suspension string and 15 units in each of two parallel

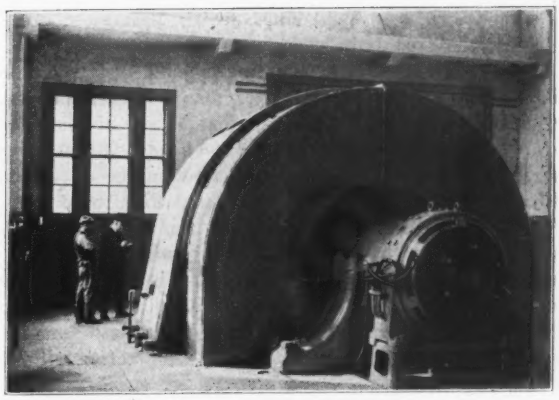


FIG. 3. SYNCHRONOUS CONDENSER FOR POWER FACTOR CORRECTION ON SOUTHERN CALIFORNIA EDISON CO.'S SYSTEM

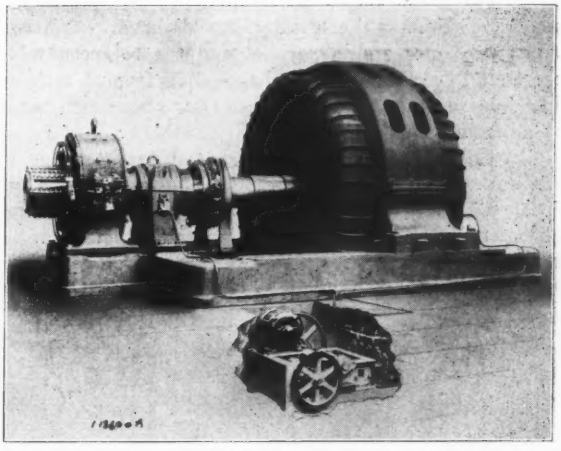


FIG. 4. STARTING TORQUE OF THIS PHASE MODIFIER IS REDUCED BY FORCED LUBRICATION OF BEARINGS

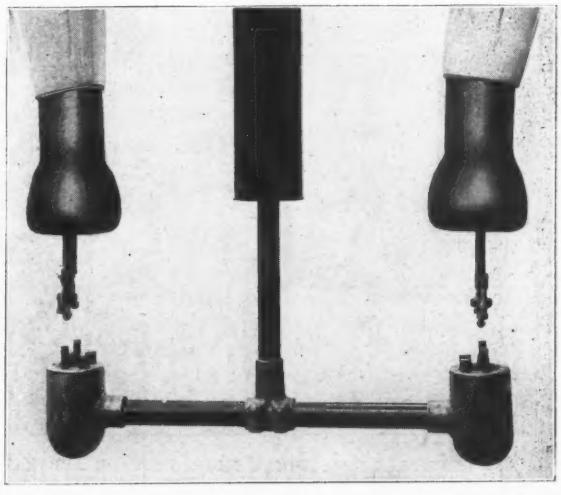


FIG. 5. THIS 110-KV. CIRCUIT BREAKER IS EQUIPPED WITH AUXILIARY ARCING CONTACTS

dead end strings. Shield rings are of aluminum, except those at the top of the suspension strings.

Practically the only operating trouble on these lines has been from flashovers. After many observations and experiments, it was concluded that many of these are caused by birds. In August, 1923, 14 such flashovers occurred. V-guards were at first placed on the towers but did not materially stop the flashovers. Finally 60 mi. of line were equipped with galvanized iron bird pans in the crossarms above the center string of insulators. Since this was done in February, 1924, there have been no flashovers on this part of the line and only 4 on the whole line. Laboratory tests have also indicated that flashovers may be caused by dirt on the insulators in combination with fog or dew.

Balanced Relays Handle Flashovers on Big Creek Line

When the Big Creek line was first installed, flashover control was entirely manual. After some experimenting on the 60-kv. network, balanced relays were installed on the 220-kv. lines, together with the other necessary equipment to handle automatically the flashover conditions. When two lines are in parallel and the balanced relays operating, the flashovers are handled in from 2 to 5 sec. The relay operations on these lines have been satisfactory in all cases.

Investigations have been conducted to determine the amount of vibration in these lines, but no definite conclusions have as yet been reached as to the cause of the vibration and the means of preventing it. The vibration of the conductors is nearly always in a vertical plane; little horizontal displacement has been observed. A simple recording device, actuated by a string thrown over one of the conductors, has shown vibrations in some spans of as much as 1 in. in amplitude, with frequencies of from 13 to 30 cycles per sec. In some cases the vibrations are purely mechanical, while in others the mechanical forces do not seem to account for the vibrations observed. Many spans never vibrate, while some are particularly subject to vibration, the longer spans being particularly susceptible. The places most affected are at dead-end clamps and places where the waves are reflected. The most promising method of preventing this is to provide a joint where movement can take place without bending or shock to the cable, and a joint has now been developed for that purpose.

Investigations of surges in the 220-kv. lines at Big Creek have been made, home made photographic apparatus being used at first and more recently the Klydonograph developed by the Westinghouse Electric & Manufacturing Co. It has been found, from the records thus obtained, that 51.0 per cent of the surges were less than 1.25 times normal and 99.3 per cent were less than 2.25 times normal. The investigations lead to the belief that switching may be done safely and that on this particular line, with its degree of insulation and climatic conditions, no surges would occur of sufficient magnitude to cause trouble.

From the Pit River plants of the Pacific Gas & Electric Co. two transmission lines run to the substation at Vaca on separate structures for 60 mi. and then on a two-circuit steel tower line for 142 mi. to Vaca. Both these circuits were operated at 125 kv. until November, 1923, when one was changed to 220 kv. These two lines are connected to transformer banks at the two ends and the low

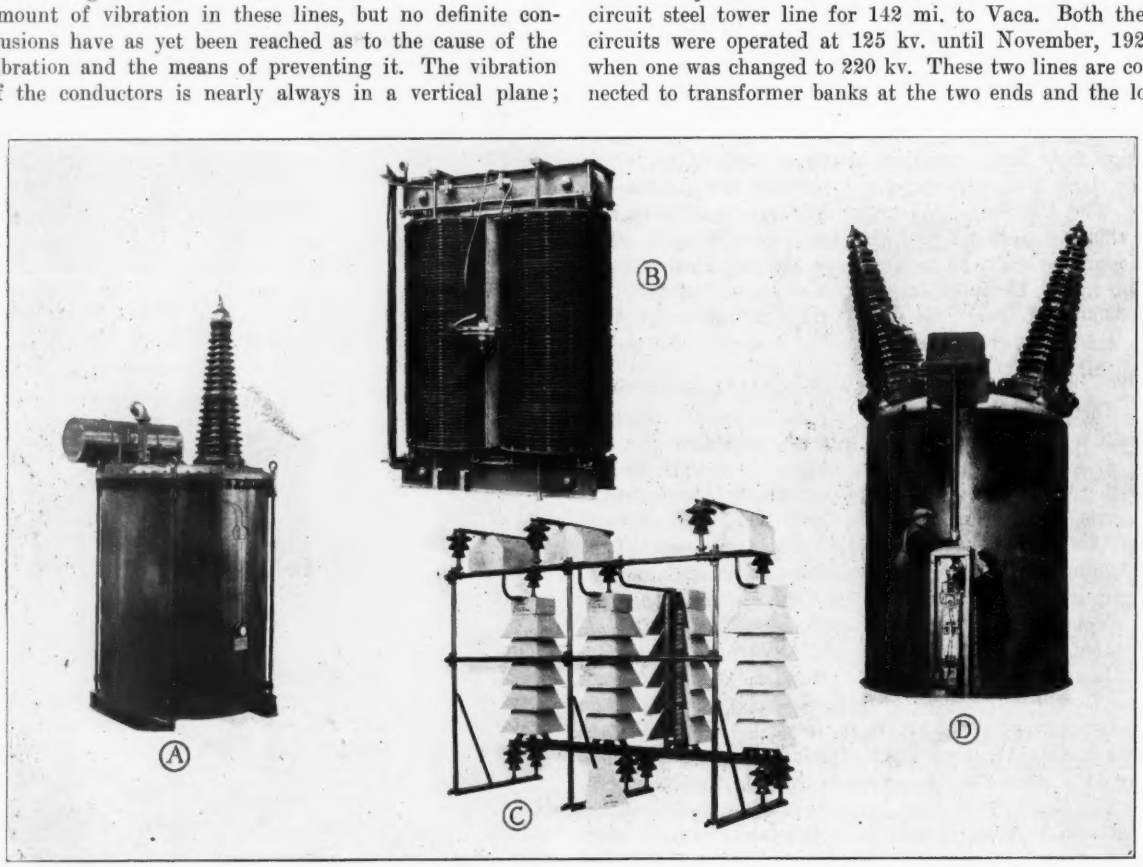


FIG. 6. EXAMPLES OF TYPICAL HIGH VOLTAGE APPARATUS. A. GROUNDED SIDE OF A 127,000/220,000/11,000-V. OUTDOOR TRANSFORMER. B. HIGH VOLTAGE SIDE OF A 220,000-V. OUTDOOR TRANSFORMER. C. OXIDE FILM LIGHTNING ARRESTER FOR OUTDOOR SERVICE. D. INSERTING COVER PIPE AND CONNECTING SOLENOID TO OPERATING MECHANISM ON A 220,000-V. BREAKER

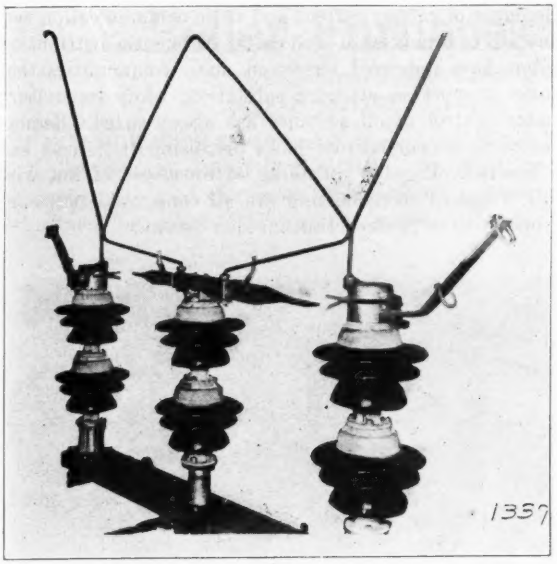


FIG. 7. ON THIS 154-KV. DISCONNECT SWITCH THE MAIN CONTACT RELEASES AS SHOWN BEFORE THE HORN GAP OPENS

voltage sides of these banks are connected to common buses. Two sets of directional relays, one operated from line current and the other from ground or residual current. A few automatic operations have occurred since the beginning of the 220-kv. service and in each case correct relay performance has taken place. There has been no physical damage to the line or insulators as a result of the flashovers that have occurred. There has been one physical break of a conductor due to a defective factory coupling.

In general, the conclusion to be drawn from the experiences of these two 220-kv. lines is that the standard methods and procedures for the operation of 110-kv. lines can be continued in the higher voltage operations. It is necessary only to add a few precautions on account of the greater charging currents and the voltage rises they cause.

Equipment for Voltage Regulation and Power Factor Correction Must Be Installed

Among the important problems of high tension transmission are those of voltage regulation and control of wattless current in the distribution systems. These problems are simply two different phases of the same general problem of power factor correction. On account of the resistance of the conductors being in phase with the current, there is a voltage drop in the transmission lines and, in addition, a reactance voltage drop due to self-induction of the conductors. This reactance drop may have great influence in increasing or decreasing the line voltage and if the line is long, the frequency high or the power large, may influence the line drop. By employing phase modifiers, the phase or direction of this induced voltage may be controlled. Of course, a certain amount of self-induction in a transmission line is an advantage, because it allows the voltage at the receiving end to be held constant by means of phase modifiers or synchronous condensers.

Present interconnected systems necessitate the use of selective relays on various switches. The problem of voltage regulation has been met largely by regulation of feeders at substations and distribution centers with induction type regulators.

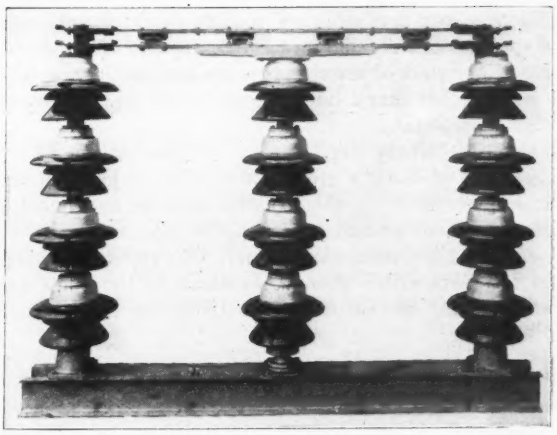


FIG. 8. A DISCONNECT SWITCH FOR 220-KV. SERVICE

The development of improved and more rugged types of bushings has facilitated the design of high tension switching devices. Oil insulation is used in American practice and the latest practice is to install much of this equipment out of doors. The large breakers used here involve long travel of the contacts and a heavy moving element. In some cases an auxiliary latch holds arcing contacts together as shown in Fig. 5; when the main contacts are separated, and after the moving member has moved about 7 in., the latch releases and a spring retrieves the upper contact, breaking the circuit quickly.

Disconnecting switches are commonly used to isolate circuit breakers from bus bars or incoming lines to facilitate inspection. In the case of high voltage units, it is customary to make them in the form of multipole units, mechanically operated. If it is desired to use a disconnecting switch for opening the circuit under load or for opening the charging current of the line, it is necessary to provide fuses, arcing horns or similar devices as shown in Fig. 7, for carrying off the arc formed. The switch shown is for 154-kv. operation, the arcing horns being twisted at an angle to the blades so that the latter will be some distance out before the horns release, thus insuring that the circuit will not be opened on the main contacts.

Various Types of Lightning Arresters Protect Lines

To secure the maximum amount of protection on power transmission systems, lightning arresters of the electrolytic type are almost universal practice. Figure 9 shows one of these arresters, built for 132-kv. service, showing the tank, bushings, trays and support. The gaps used with such lightning arresters may be of either the horn, sphere or impulse types.

In many cases the horn gap, which was the first one to be used, is still employed. The sphere gap has a greater speed of discharge than the horn gap, and is usually equipped with a horn extension rising above the spheres to assist the arc to rise and be extinguished. The latest development is the impulse gap which has a negative time lag; that is, the higher the frequency, the lower the voltage at which it discharges. Thus the impulse gap automatically selects the dangerous surges, prevents too frequent discharging on minor surges and gives protection more quickly than any other type of gap.

Although the electrolytic type of arrester offers the best protection, its first cost is high and it should be charged at least once a day. The auto valve type of arrester

is lower in cost and does not require charging, although these advantages are obtained at the expense of protective ability. Arresters of several types are used in the majority of systems, but many lines operate at 60 kv. and above without arresters.

One exceedingly live issue at the present time is the advisability of using a ground wire. The majority of the transmission lines in this country operate as grounded systems without ground resistance. Several recent installations use a low resistance ground. One system has operated for years with a ground resistance of 100 ohms and many systems operate entirely without ground. Ground

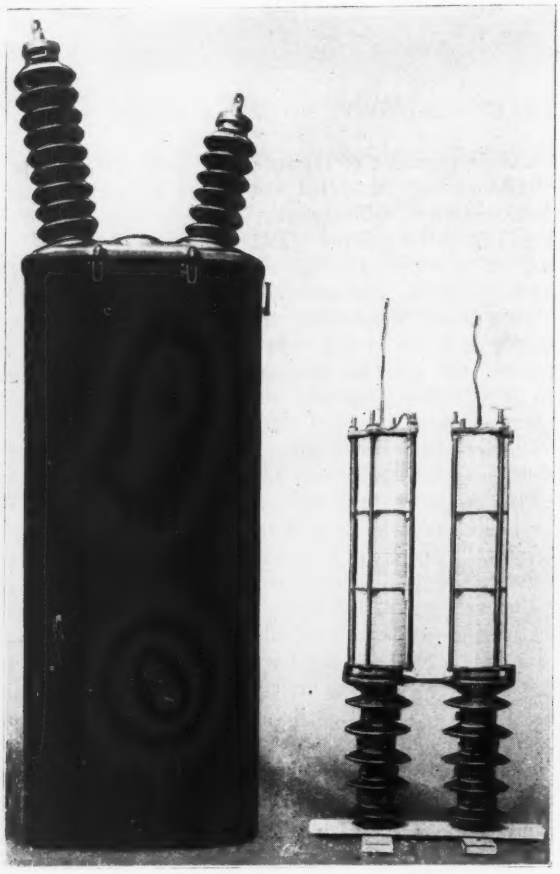


FIG. 9. LIGHTNING ARRESTER FOR 132-KV. SERVICE, WITH TRAYS AND SUPPORTS SHOWN AT THE RIGHT

wires are used on the majority of existing systems, but the trend in more recent installations is toward their omission. There is, nevertheless, a wide difference of opinion.

Good Dispatching Is Essential

When unified, interconnecting systems were first developed, the operating departments handled many of the problems of operation as they arose. Further complications under modern conditions, however, have dictated the policy of training system operators or load dispatchers. Men of good judgment and training are needed for this important work, on which depends so much of the safety of men and equipment.

In operating a large system, it is necessary to have operators at many different points, and some form of communication system must be used to supervise them. Development of carrier current and radio communication systems will be beneficial in such cases. Automatic distribution centers have improved service in many communities that cannot support an attended substation, while supervisory remote control of oil switches has also assisted. Remote control by carrier current looks promising if its cost can be lowered. Regular patrolling of lines, use of hot wire tools, frequent sectionalizing are all considered necessary in operating a modern transmission system.

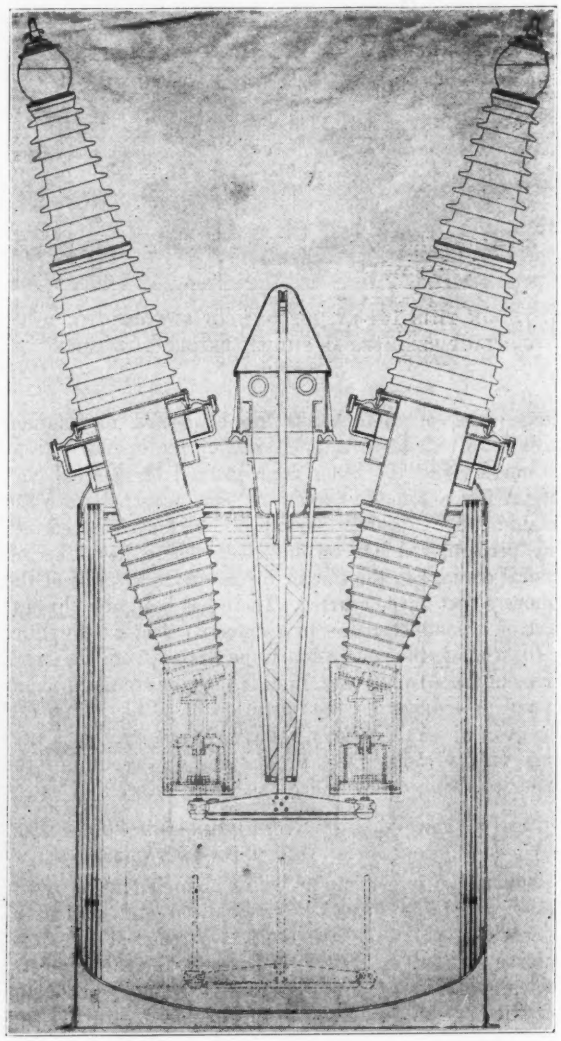


FIG. 10. CROSS-SECTION OF ONE UNIT OF 220-KV. OIL CIRCUIT BREAKER

In concluding this article, we acknowledge our indebtedness to Westinghouse Electric and Mfg. Co., the General Electric Co. and to Herbert W. Young, of the Delta Star Electric Co. for photographs and other information used in its preparation.

ALL TANKS should have their outlets at least one foot off the bottom and should be equipped with suitable drain outlet for cleaning, flushing, etc.

AIDING those over whom you have triumphed adds to your greatness.

Boiler Furnaces for Pulverized Coal

DESCRIBING A NEW TYPE OF FURNACE WITH A COMBUSTION RATE OF OVER HALF A MILLION B.T.U. PER CU. FT. BY H. W. BROOKS*

IT IS KNOWN THAT the speed of combustion and the length of flame travel in furnaces is dependent upon the rapid mixing of the gases. Few engineers, however, understand the extent of this mixing necessary.

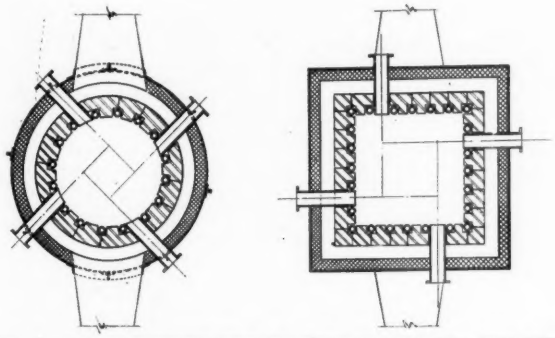


FIG. 1. PLAN SHOWING THE PLACING OF JETS IN BOTH THE CIRCULAR AND SQUARE POT FURNACES

The sieve opening in a 200 mesh screen (U. S. Series) is given as 74 microns (0.074 mm.). For convenience in calculation let us consider for the moment a pulverized coal particle consisting of a 70 micron cube. According to the Smithsonian Institution there are at 760 mm. and zero degrees centigrade, in a cubic centimeter of any gas

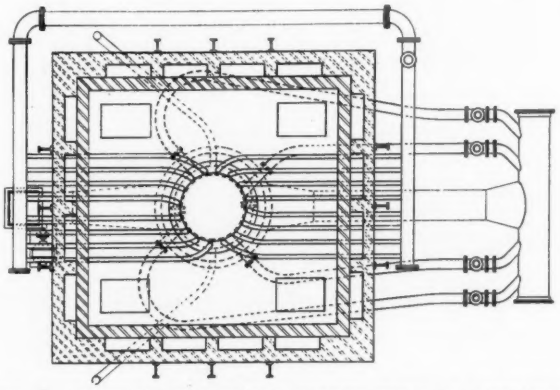


FIG. 2. PLAN OF THE WATER COOLED WELL AS ACTUALLY APPLIED TO ONE OF THE LATER DESIGNS

including air, 27 million billions of gas molecules, the oxygen atom having a radius of three billionths of a centimeter. Dividing then the number of oxygen atoms per cubic centimeter by the number of 70 micron coal cubes per cubic centimeter, we find that each average coal particle must split up into nine thousand three hundred billion carbon atoms and each must locate its corresponding oxygen molecule. Such figures obviously mean little to us. Let us, therefore, multiply the size so that we may better visualize the process. The air ship "Los Angeles" is 650 ft. long, and has a total volume of 2,700,000 cu. ft. Let us consider then the carbon particle as a balloon the size of the air ship "Los Angeles." The comparative size of the oxygen atom would then be somewhat less than an .08 inch cube, or let us say about the size of a gnat.

Picture then the "Los Angeles," representing the coal particle, moving through the air either horizontally at a rate of somewhat less than a mile a minute or vertically at somewhat more than a mile a minute, carrying entrained along with it at approximately the same speed some twelve thousand billion gnats, representing the oxygen atoms. (For simplicity it is assumed that all air is introduced as primary air, including 30 per cent excess). Each of these

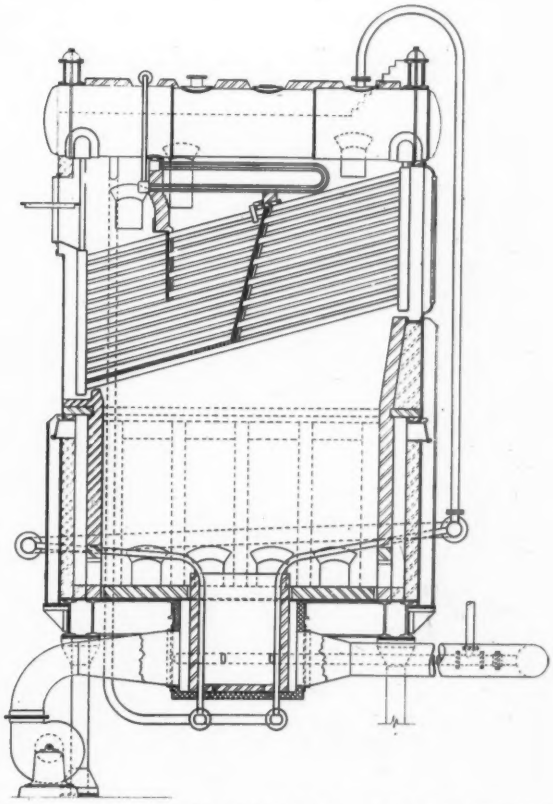


FIG. 3. RECENT APPLICATION OF THE WELL TYPE FURNACE TO A BOILER INSTALLATION

gnats in addition to its lineal speed is vibrating in a fixed orbit at a velocity many times the speed of a bullet, and measured in miles per second. Complete combustion necessitates our air-ship-sized coal particle disintegrating into some nine thousand three hundred billion pieces and combining with a corresponding number of the gnat sized oxygen molecules.

In stoker firing with pieces of coal millions of times the size of our pulverized coal particle we aid the disintegration but little, leaving nature to take its course. In pulverizing coal, we assisted the natural processes somewhat by reducing the particle size before firing. We at least *began* to appreciate the huge task a piece of coal assumed in disintegration, though only in part did we aid the natural process of diffusion and atomic attraction which brought the carbon atom and the oxygen molecule together.

*Consulting Engineer, Fuller-Lehigh Co., Fullerton, Pa.
A discussion presented at the Pulverized Fuel Session of the spring meeting of the A. S. M. E.

Many writers on combustion in the past have stressed the importance of turbulent flow, agitation and mixing to aid the natural diffusivity but a practical means of accomplishing this mixing has heretofore remained undiscovered.

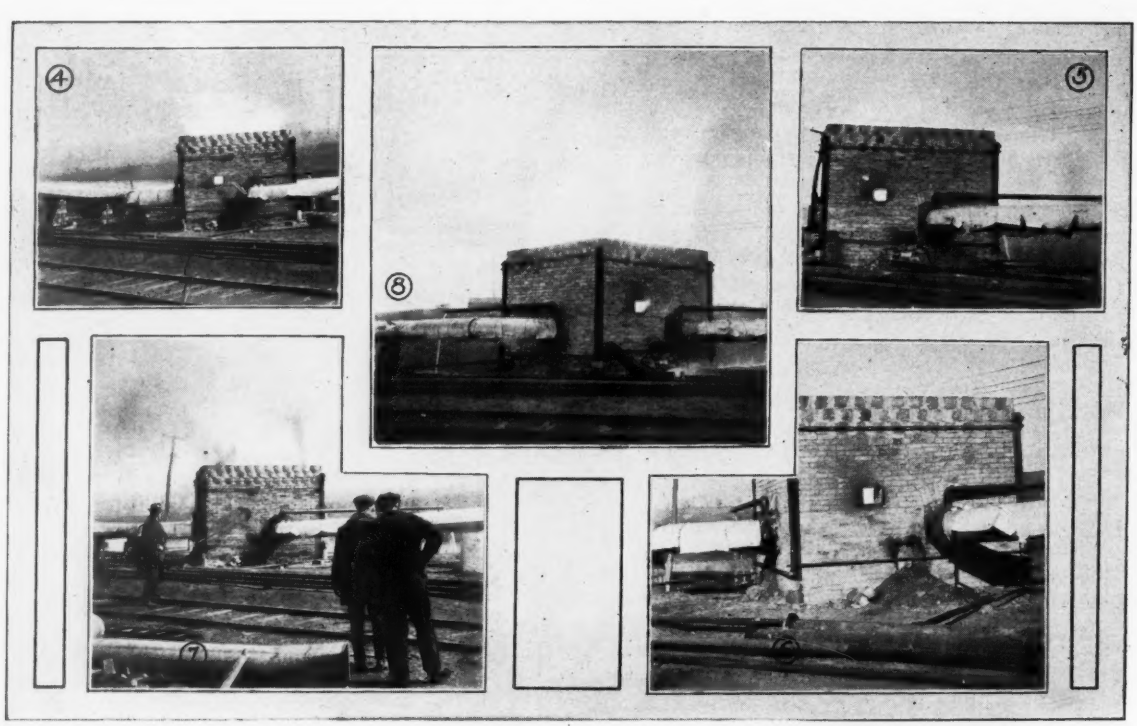
Several years ago it occurred to one of the engineers of the Fuller-Lehigh Co. that one of the most intense manifestations in nature of turbulent flow and agitation of gases and particles in suspension was in the tornado, where it had been repeatedly demonstrated that materials of considerable tensile strength had actually been torn apart, disintegrated and reduced to fine pieces and sometimes to powder by the intense centrifugal action of the air. Experiments were started at Fullerton on a small furnace 18 in. square by 3 ft. deep in which the jets were placed to throw the flame tangent to the tornado of the fire within the furnace, the flame of the first jet being deflected before it reached the refractory walls by the impingement with equal velocity at right angles of the flame from the second jet, the third jet again changing the direction 90 deg., and the fourth jet completing the tornado within the pot.

Figure 1 shows the placing of these jets both in the circular and the square pot furnaces.

It was well known that the external walls of the tornado of nature had been observed to be rather sharply defined from the surrounding air. Thus it was decided to adapt this principle by placing the pulverized fuel jets in such relation to the refractory walls that there was little, if any, impingement of the fuel tornado on the furnace walls. As was anticipated, therefore, the refractory walls showed little damage due to erosion, and thermocouple temperatures taken on the inner refractory surface of the furnace showed that the inner face of the brick never exceeded 2700—2900 deg. F.

It had also long been recognized that the transmission of sensible heat from the hot gases from the furnace through the tubes of the boilers to the water on the other side was limited by the existence at the boundary surface of a "dead film," generally assumed to be about 1/40 of an inch in thickness, of relatively cool gas in which convection currents apparently did not take place, and which owing to its low conductivity offered a high resistance to the passage of heat (other than radiant) through it. This "dead film" is the main and most potent obstacle to rapid heat transmission in the boiler, and it follows that its complete or even partial destruction will greatly assist the flow of heat and hence the efficiency of the boiler. Prof. J. T. Nicolson of the Manchester School of Technology demonstrated a formula proving that the heat transfer was a direct function of the velocity of molecular travel of gases passing the tubes. Thus it was anticipated and tests subsequently proved that with the higher scouring action of the swirling gases in meeting the boiler tubes there would not only be a higher rate of heat transfer and higher boiler efficiency, but also a cleansing action which would keep the tubes clear of deposited ash.

Early during the experiments the nature of the ignition and combustion taking place in the well proved quite unlike anything experienced pulverized fuel engineers had hitherto seen in powdered coal combustion. The flame itself resembled that of a blow torch, virtually a "ball of fire," combustion apparently taking place in a limited zone within the well. By regulating air admission and air pressure it was possible to move the hottest zone into the well



FIGS. 4-8. VIEWS OF THE EXPERIMENTAL FURNACE AT FULLERTON

Figs. 4 and 5. The Well Type of Furnace in Action. Fig. 6. Furnace Just Prior to Ignition. Fig. 7. Furnace Immediately After Ignition. Fig. 8. The Coal Equivalent Necessary to Operate a 1500-Hp. Boiler at 632 Per Cent of Rating Being Burned in the Experimental Furnace

itself or to a point just in front of the well. Appreciating further the gains due to the more efficient transfer of heat by radiant energy as a result of this "ball of fire," the inventor had still further reason to expect efficiencies higher than had been before demonstrated in pulverized fuel combustion, as well as a flatter overall performance curve at high ratings.

These experiments were kept secret for several years, until finally a favored few of the larger operators were shown the experimental furnace at Fullerton. Several immediately volunteered to install a furnace of the new type, but the results which indicated heat releases many times greater per cubic foot of combustion volume than had ever been before accomplished were so revolutionary in character that the company felt it best to withhold a commercial scale installation until they had finally and thoroughly convinced themselves that no practical operating difficulties would intervene.

Finally on February 5, 1924, an agreement was entered into with the United Electric Light and Power Co. of New York City by which a commercial scale experimental installation of the new furnace would be made at their Sherman Creek Station alongside five other boilers fired by the older pulverized fuel firing methods being exploited by various manufacturers. By thus conducting six simultaneous tests on six different systems under similar conditions the new furnace construction would not only be subjected to a large scale test, but at the same time could be directly compared with five competitive systems.

It was particularly fortunate for the inventor that the operating company themselves expressed the desire to make the tests entirely with their own personnel. In this manner the natural enthusiasm of the creator could not inadvertently be injected into the testing technique and the results as obtained would be those of non-partisan observers, actuated entirely by a desire to seek for themselves the *truth*. Today it is understood these tests have been completed. It had been our hope to be able to present them at this meeting. This having not proven convenient to the authorities of the United Electric Light & Power Co., we shall look forward to the privilege of their presentation at some later meeting. We are permitted to state, however, that the efficiencies have actually proved from 3 to 5 per cent higher than with any other method of firing, and the curve of efficiencies at various ratings has been much flatter than anything heretofore demonstrated.

In Fig. 3 is shown a diagram of one of the more recent applications of this furnace. From this section it will be noted that above the well there is provided a dispersion chamber in which the hot gases after burning are allowed to expand before reaching the boiler tubes, thus reducing the tornado effect to a value which can cause no possible erosive effect on the boiler tubes. The theory of this chamber was to allow just sufficient velocity to scour off the "dead film" from the boiler tubes without going any further in attacking the tubes themselves. It is not possible to state at this time the minimum size to which this chamber may eventually be reduced. It has definitely been established, however, that the combined volume of well and dispersion chamber can be made substantially less than the combustion space provided in the old fashioned stoker setting. Knowing that we can convert present stoker fired settings by this means, and attain the highest boiler ratings desired, there is at this time no occasion to go further until the application is extended to other services, such as transportation and marine.

Simultaneous with the tests at New York research has been continued at Fullerton on a furnace consisting of an 8 ft. cube.

Views of this furnace are shown in Figs. 4 to 8.

Figure 8 shows the remarkable phenomenon of the coal equivalent of a 1500-hp. boiler at 632 per cent of rating being burned in the volume of an 8 ft. cube!

Eliminating Waste in Industry

INCREASING INTEREST on the part of industry as to the benefits of simplified practice was an outstanding feature of the work of the Division of Simplified Practice during the first quarter of 1925, says a report to Secretary of Commerce Hoover from Ray M. Hudson, chief of the Division. During the quarter four important simplification programs were put into effect. These included the reduction of commercial forms, including inquiry, purchase order and invoice forms from thousands of varieties to three; the reduction in sizes of sand lime brick from 14 to 3; and the reduction of varieties of milling cutters from 944 to 570. Another important action during the quarter was the revision of varieties of paving brick, with a reduction from five to four "recognized sizes". This industry, one of the first to cooperate with the Division in weeding out excess varieties, started 4 yr. ago, when 66 varieties were made. Surveys revealed that demand was concentrated largely in 11 sizes. In successive conferences those sizes which fail to supply a certain small percentage of the demand have been weeded out until but four remain.

Probably the most widespread impact on commerce through simplification will be found to be the reduction of varieties of inquiry, purchase order and invoice forms; it has been claimed by the National Association of Purchasing Agents that savings of more than $15,000,000 are possible annually in misunderstandings, clerical help and other wastes to the business houses of the country.

In the field of marine standards, the American Marine Standards Committee, working in cooperation with the Division, has issued to the entire marine industry its standards for fixed lights, glass for airports and fixed lights, and for double barreled bitts. Tentative standards are nearing completion for such subjects as the following: Oil-tight hatch fittings, metal gratings for machinery, sundry deck fittings, instructions for the care and operation of boilers and superheaters, regulations covering fire hazards, grading of valves, safety equipment, spare parts and insulation of piping and machinery.

Active projects upon which the Division is at work include some 55 items, among which seven have to do with the automotive industry and eight of which have to do with lumber or the woodworking industries. The report points to the wide attention which is being paid to the simplified practice movement in newspapers and trade journals in this country, and refers to requests from many foreign countries. The foreign inquiries are taken as an indication that the movement holds a suggested remedy for industrial problems abroad. As a further proof of the interest of business and industry in the possibilities of the simplification movement, the Division's experts are in constant demand to address meetings of trade bodies, business executives, and other gatherings, it is stated.

Horsepower Transmitted by Wire Rope

By W. F. Schaphorst

HAVING had occasion to study the problem of power transmitted by wire rope I found very little trustworthy material on the subject. Some tables give results over five times higher than others. I did not find any simple rules or formulas such as we have in power transmission through belting.

After a study of my books and a number of manufacturer's catalogs, I derived the following rule which I consider safe for wire rope on wood filled sheaves, the rope being made of cast steel wire.

"Square the diameter of the rope in inches, multiply by the diameter of the sheave in inches, then multiply by the revolutions per minute of the sheave, and then multiply by 0.03. The result is the horsepower transmission capacity." If the rope is made of iron, divide by 2. If the grooves are filled with leather or rubber, add 30 per cent.

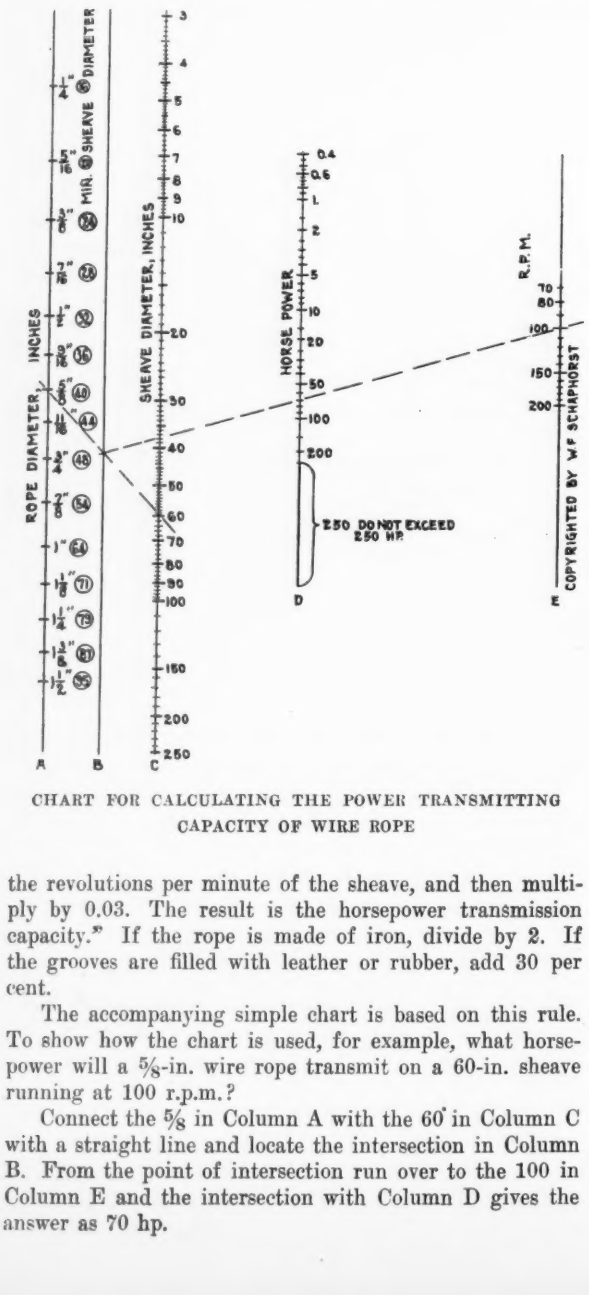


CHART FOR CALCULATING THE POWER TRANSMITTING CAPACITY OF WIRE ROPE

The accompanying simple chart is based on this rule. To show how the chart is used, for example, what horsepower will a 5/8-in. wire rope transmit on a 60-in. sheave running at 100 r.p.m.?

Connect the 5/8 in Column A with the 60 in Column C with a straight line and locate the intersection in Column B. From the point of intersection run over to the 100 in Column E and the intersection with Column D gives the answer as 70 hp.

The range of the chart is great enough to cover practically all sizes of wire rope from 1/4 to 1 1/2 in. and all sheave diameters from 3 to 250 in. The horsepower varies from 0.4 to 250. One authority states that 250 hp. should never be exceeded in wire rope transmission, consequently for the sake of safety I have made 250 hp. the limit and should any intersection fall below the point 250 in Column D the chart will show the answer to be 250 hp.

If the rope is made of iron, divide the horsepower obtained in Column D by 2. If the grooves are filled with leather or rubber 30 per cent may be added to Column D.

MINIMUM SHEAVE SIZES FOR GIVEN ROPE DIAMETER

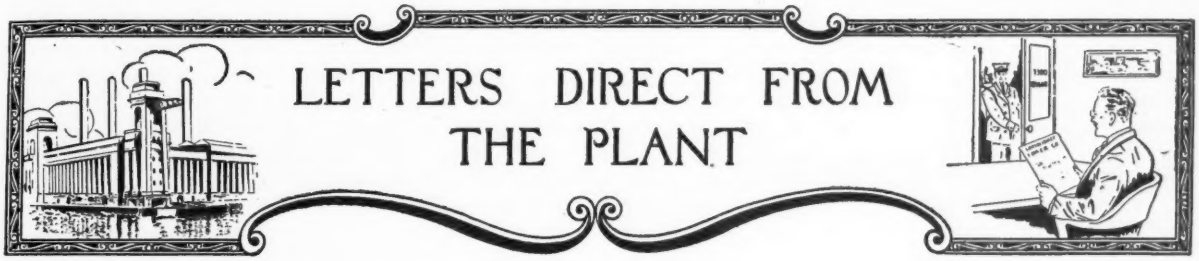
Rope Diam. Inches	Minimum Sheave Diam. Steel Rope Inches	Minimum Sheave Diam. Iron Rope Inches
1/4	16	32
5/16	20	40
3/8	24	48
7/16	28	56
1/2	32	64
9/16	36	72
5/8	40	80
11/16	44	88
3/4	48	96
7/8	54	108
1	64	128
1 1/8	71	142
1 1/4	79	158
1 3/8	87	174
1 1/2	95	190

After each rope diameter in Column A, I have enclosed a figure in a circle which in every instance is the minimum sheave diameter that should be used with the rope size. For example, if it is a 7/16-in. rope, do not use a sheave smaller in diameter than 28 in. for steel rope. For iron rope a sheave twice as large as for steel rope should be used in which instance the figures within the circle should be multiplied by 2. It is well to use sheaves that are amply large in diameter. Large sheaves cost more but they cause the rope to bend less and consequently the rope will have a longer life.

In order that there will be no mistake about the matter of minimum sheave diameter, I am submitting the same information as contained in Column A in tabular form below.

Distilled Feed Water Helps Boiler Equipment

In the article with the above title that appeared in the May 15 issue, the word "ellipticoils" was inadvertently inserted in the cut caption of Fig. 4 on page 532. This cut does not show "ellipticoils" as stated; instead, it shows a cross-section of a contraflo submerged type of high pressure evaporator, as illustrated in Fig. 3 on the same page, the coils being doubly recurved to allow for expansion and to aid in cracking scale. The ellipticoil is shaped differently and is flattened to an elliptical cross section throughout its length.



Should All Industrial Plants Buy Power?

IN THE May 15 issue of Power Plant Engineering, it was stated that one of the recommendations prepared by a committee for the consideration of the International Chamber of Commerce meeting at Brussels in June is as follows: "The power in industrial plants to be electrical from central power stations linked to the general electrical network." This recommendation if carried out will be a great step in conserving the fuel resources of the nation, but it should be borne in mind that central station power cannot be applied to all industrial plants. Quite a number must have live steam for process work and in most of these plants it would not be economical to buy electricity for power and then be compelled to maintain a boiler room in addition. Such industries as these would probably find it cheaper to generate their own electrical power.

The writer has in mind a typical paper mill which is representative of a class of plants that are of the largest coal users in the industrial system. As an example, we will consider a mill producing 25 T. of high grade linen paper per day and compare its cost of power production with a modern central station using 1 lb. coal to generate 1 kw-hr.

The power requirements of the mill will be about 1000 hp. in a two-machine mill, 160 hp. developed in the machine room and 840 hp. on the main shaft. There is no doubt that there is plenty of room for improvement in the performance of a paper mill power plant, but the logical way to save coal is by installing the correct equipment and improving operating methods. We will assume that this mill is purchasing its power. It must operate a boiler plant to furnish steam for drying paper and bleaching rags. The steam consumed in the machine room will be about 9000 lb. per hr. or about 4 lb. of steam per lb. of paper. The bleach boiler will require 3000 lb. per hr. at a pressure of 20 to 25 lb. The pressure in the driers will not need to be over 15 lb. With an evaporation of 8 lb. of water per lb. of coal the coal consumption will be 1500 lb. per hr. or 18 T. per day. About 750 kw. must be purchased to supply the total power requirements.

With 1 lb. of coal burned per kw-hr. in the central station, it is obvious that we must add 250 lb. of coal to the amount burned in the mill boiler plant to find the total quantity of coal needed to run the mill. The total is 1⅛ T. and since the mill runs 24 hr. per day, the total coal consumption to supply process steam and electric power is 27 T.

Now we will make an estimate of the coal required to furnish power and process steam if the paper manufacturer generated his own power. To generate 1000 hp. on less fuel than the central station uses is the problem to solve, since the process steam requirements are the same, regardless of the power supply. If we can generate our power by passing 12,000 lb. of steam through an engine and exhausting at 15 lb. back pressure into the driers and bleach boiler, obviously this is the most economical method, since the additional coal required will be negligible. But to generate 1000 hp. on 12,000 lb. of steam with a non-condensing engine requires an efficient unit, high pressure and superheat. If we generate steam through a compound engine of the Lentz type, we can secure a water rate as low as 12 lb. per hp. non-condensing. It will take about 11 per cent more coal to generate steam at 300 lb. than if low pressure steam was generated. Since 1500 lb. per hr. was burned to generate low pressure steam, the only fuel that can be charged to generating power is, 11 per cent × 1200, or 165 lb. per hr. Then,

$$\frac{165}{750} = 0.22 \text{ lb. of coal per kw-hr.}$$

Now, how can any fuel be saved by purchasing power from a central station whose turbines use 1 lb. of coal per kw-hr. when it can be generated in the consumer's own plant for less than ¼ this amount with the proper type of engine? The greatest fuel saving system that can be devised is the use of high pressure steam (300 to 500 lb.) in non-condensing engines in industrial plants where process steam is required. Yet this plan has been completely overlooked. Of course in many industrial plants it will not be necessary to go to such high pressures. Suppose a plant required 1000 hp. and also required 25,000 lb. of steam per hr. at 5 lb. pressure, then a simple Corliss engine would be the proper prime mover with an initial pressure of only about 150 lb., since the required water rate is 25 lb. per hp.—a figure easy to attain.

On the other hand, we must admit that many industries, such as the metal trades, do not require process steam and without doubt they should buy power. But even these plants should not purchase all their power. The writer is acquainted with some plants of this type that in winter require as high as 18,000 lb. of steam per hr. to heat the buildings. With a uniflow engine or an economical type of four-valve counterflow engine expanding steam from 200 lb. pressure, 150 deg. superheat to 2 lb. pressure, a water rate of 22 lb. per kw-hr. could be obtained and 818 kw. could be generated where heating requirements are 18,000 lb. per hr. Any power over and above this amount could be purchased and possibly some fuel would be saved. Ordinarily, however, there is no saving for an industrial plant needing process steam to buy its power.

Holyoke, Mass. A. F. SHEEHAN.

Common Gasket Practice

POOR PRACTICE and resultant failures in the use of gaskets should be discussed as freely as successes and good practice. For example, years ago, when I was an erector

of ammonia machinery, I did a thing which I now realize my common sense should never have permitted. It may not have caused any serious trouble but the elements of danger were there and it would be interesting to know what eventually happened.

In bolting a pair of ammonia flanges together, I inadvertently selected bolts which, although of correct diameter, were not long enough to take the full thread of the nuts. The proper procedure would have been to get longer bolts, but the boss was near and I was afraid he'd "bawl me out" for being such a boob in not selecting the right bolts in the first place. So I started screwing down on the nuts with such force that finally the ends of the bolts were brought flush with the top of the nuts. When I was through, everything appeared satisfactory; but I knew it was wrong. I presume I squashed the gasket until very little remained in the seat and there is little doubt that the bolts were actually stretched.

Stretching bolts is bad practice. Probably I passed the elastic limit and all the bolts were on the point of breaking, or in a weakened condition when I finished. Whenever a rod under tension begins to reduce in cross-sectional area, its strength is much less than normal and rupture is imminent.

In this case it was not necessary to lengthen the wrench, although I was deliberately using force, whereas in many cases, by slipping a pipe on the handle, wrenches are lengthened and extra force used quite unconsciously. Lengthening wrenches and applying too much pressure has been the cause of many accidents. This applies to other lines of work as well as poor gasket practice.

Newark, N. J. W. F. SCHAPHORST.

Does Oxygen in Feed Water Cause Pitting?

IN YOUR ISSUE of March 1, there appeared an article entitled "Colloidal Purification of Feed Water," by C. H. S. Tupholme and in the April 1 issue, comments by F. F. Vater were published in which he disagreed with Mr. Tupholme's statement that dissolved oxygen causes pitting in boilers.

My experience has been such that I am inclined to agree with Mr. Tupholme that dissolved oxygen does cause pitting. I might call Mr. Vater's attention to the fact that in our plant we had considerable trouble with corrosion especially in our boiler feed lines although not much in our boilers, due to the fact that the corrosive ingredients could not get into the boiler on account of the boiler feed line having about 2 ft. drop before entering the boilers.

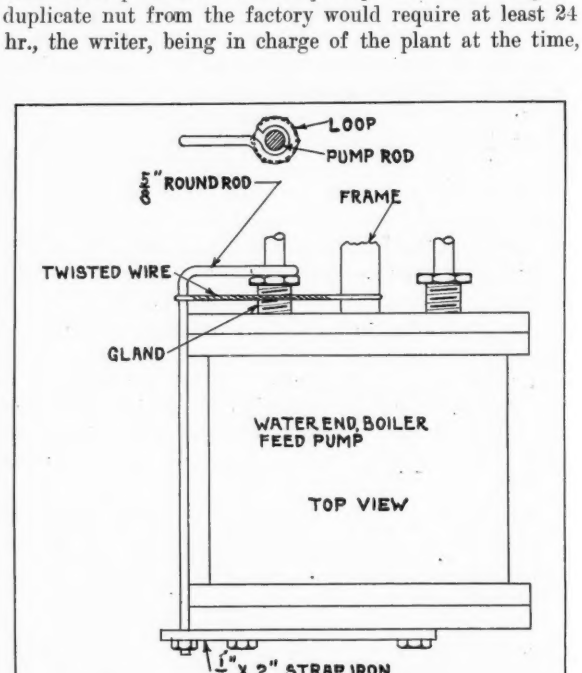
We found upon examination that with a temperature of 140 deg. F., we had an oxygen content in our boiler feed water of 3.07 c.c. per liter, at 190 deg. we had 0.698 c.c. per liter, at 200 deg. we had 0.2435 c.c. per liter, and at 206 we had 0.1396 c.c. per liter. Our operating conditions were such that at times our water temperature was as low as 140 to 145 deg. and it was decided that dissolved oxygen was the cause of the pitting in the feed lines since we have mostly returned condensate for boiler feed. After making this decision we installed temperature regulators to keep the water in the heaters almost at the boiling point. Since then we have had no trouble with this pitting and we have taken this as evidence that dissolved oxygen was causing this condition.

I think the difference between the two plants mentioned in Mr. Vater's letter possibly is that the water taken from the jet condensers has only a small percentage of condensate and of course any water which has scale forming ingredients in even small quantities will eliminate this corrosion or pitting caused by oxygen by precipitating a light coating of scale.

Chanute, Kansas. H. R. WILLIAMS.

Rod Used to Hold Broken Gland in Place

DURING the busy season of an ice plant in a country town a forced shutdown was caused by a broken stuffing-box nut on the water end of the boiler feed pump. As no machine shop was available for prompt service and to get a duplicate nut from the factory would require at least 24 hr., the writer, being in charge of the plant at the time,



ROD BOLTED TO CYLINDER HEAD HOLDS BROKEN PACKING GLAND IN PLACE

applied a quick temporary repair as shown by the accompanying diagram.

A flat piece of iron was drilled as shown and bolted over the water cylinder head. A round iron rod was threaded at one end and a loop turned at the other so that it would hook over the pump rod. Then this rod was bent at right angles at the proper point and placed in position with the loop against the packing gland. The threaded end of the rod was put through a hole in the strap iron which projected to one side of the cylinder head, a nut screwed on and drawn up to the proper tension. A double wire was placed around the repair rod and pump frame and twisted to hold the loop in place and so prevent scoring of the pump rod.

This temporary repair gave entire satisfaction until the required part was received from the factory.

Kansas City, Mo. H. S. FAIRCHILD.

Asbestos Cement for Pipe Covering

CAREFUL maintenance of the power plant requires constant attention to pipe covering or insulation of heaters. Often this is nothing more than a patching job, but occasionally a small section of the covering may be in such poor shape that renewal is necessary. But perhaps a new section is not available and some sort of make-shift covering must be provided. In cases like this an engineer will ordinarily use regular flake asbestos cement, but will find considerable trouble in making it stick unless wire netting is used. Even then, when the cement dries, it will crack and break open so badly that its insulating properties are worthless, even though it doesn't actually fall off.

A friend of mine has been experimenting with asbestos cements and has finally developed a mixture which he claims gives excellent results. Seven to eight parts of flake asbestos are thoroughly mixed, while dry, with one part of plaster of Paris and then water added to make a stiff mixture. This will remain soft enough for working for considerable time but cannot be re-softened if allowed to harden, as may be done with ordinary asbestos. Therefore, to get the best results, only small quantities should be mixed at a time and the desired thickness of insulation built up by successive thin layers. A smooth outer surface should be formed by constantly dipping the trowel in water, with steady, even strokes in one direction. When dry, this will make a hard uniform surface and will permit either painting or white-washing. Although not ordinarily practicable, pipes 20 to 50 ft. long have been successfully covered with this cement.

Toronto, Can. JAMES E. NOBLE.

Steam Separators Increase Plant Efficiency

MANY POWER plant operators fail to realize the value and importance of dry steam and the saving which may be effected by the use of well designed steam separators. This may be on account of little being said or written on the subject.

In plants where superheated steam is not used there is never any certain insurance against high water or priming, therefore it behooves the engineer to prevent, as far as possible, the accidents and wrecks which are often traced to water in the steam.

On several occasions the writer has seen engine fractures which operators were at loss to account for but for which to the experienced engineer there seemed little doubt that water was responsible. Some plants have operated year after year without separators and have had no serious trouble, nevertheless there is always potential danger. The use of dry steam means less wear, less cost of lubrication and increased efficiency. In many cases the installation of an efficient separator will effect enough of a saving to pay for the cost of the appliance in one month.

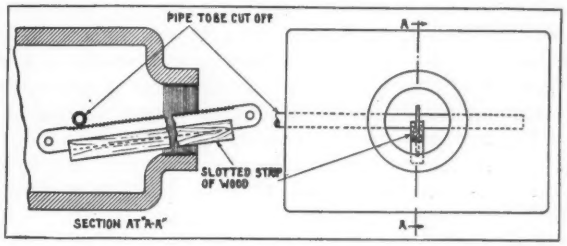
When installing a steam separator, an important point to be remembered is that the water removed from the steam would be saved and returned to the heater or boiler by means of a suitable trap. If this is not done the possible saving will be materially reduced.

There are four principal types of separators, now on the market, any one of which will give such beneficial results that the engineer who fails to avail himself of these simple means of safeguarding his engines and increasing plant efficiency should be summarily removed from the job.

Toronto, Canada. JOHN THORN.

Using a Hack Saw Without the Frame

OFTEN when working in a narrow space, the hack saw frame renders the blade of little use unless it can be held rigid by other means. Recently, it was necessary to cut off the end of a small brass pipe located on the inside of a lubricator, by reaching through a hole in the end of the body, where there was scarcely room for the insertion of a saw blade. To do this, a slot or groove was cut in the edge of a strip of wood, which was about ⅜ in. thick, ½ in. wide and about half the length of the blade. The latter was slipped into the slot and then with its improvised holder jabbed through the opening in the lubricator. This



STRIP OF WOOD HOLDS HACK SAW BLADE RIGID WHEN USED IN NARROW PLACES

is shown in the accompanying figure. The wooden strip prevented springing or bending of the blade and the end of the pipe was cut off without difficulty.

Missouri Valley, Ia. F. W. BENTLEY, JR.

Engineer's Earnings Depend on Saving

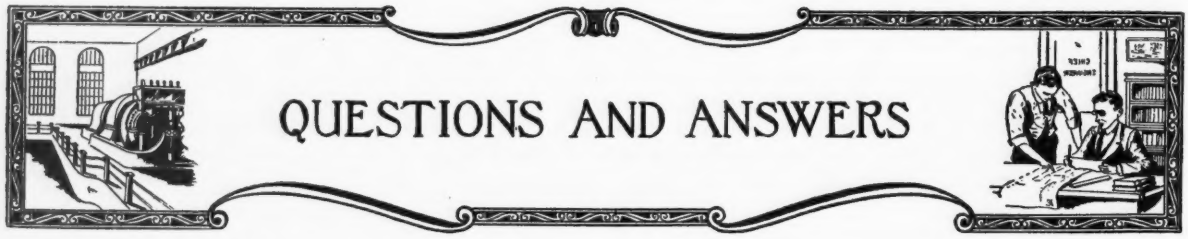
READERS will be interested to learn that the enterprising little city of Brookings, S. D., (4000 population) has decided to operate its power plant more economically. The latest move by the city commissioners is to employ Verne C. Kennedy as consulting engineer for the municipal electric light and power plant. He will not receive a salary from the city for his work but is retained on a commission basis based on the increase of net earnings which it is expected that he will bring about over the net earnings of the year 1924. He will therefore receive no money if there is no increase in efficiency of the plant. Otherwise there will be no change in the management or personnel of the power plant. His work began April 1, 1925.

The City of Brookings owns its own municipal power plant, central heating plant, waterworks system and telephone system. In addition to furnishing power and light for itself, it has a contract with the neighboring town,

Volga, S. Dak. N. G. NEAR.

STEAM FLOW-METERS should be thoroughly cleaned out once every three months. This is necessary for the reason that scale and rust from the tap lines finds its way into the flow-meter and rests upon the mercury surface and in the passages of the mechanism.

ALL FUEL OIL storage tanks should be equipped with steam smothering coils for use in case of fire.

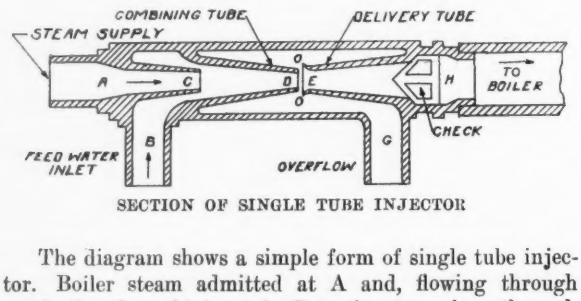


What Makes the Injector Work?

RECENTLY, in our plant, we had a discussion concerning the point of greatest pressure in a boiler. I argued that the weight of the water caused a greater pressure at the bottom. If this is true, how is it that an injector can force water into the bottom of the boiler against the pressure of the steam from which it takes its supply?

J. L. B.

A. Pressure is greatest at the bottom of the shell because at that point there is not only the pressure of the steam but also the pressure due to the depth of the water in the boilers. As the water adds only 0.434 lb. per sq. in. for each foot of depth, it may be seen that the increase of pressure due to the water may be neglected, since it is so small in comparison with the steam pressure.



SECTION OF SINGLE TUBE INJECTOR

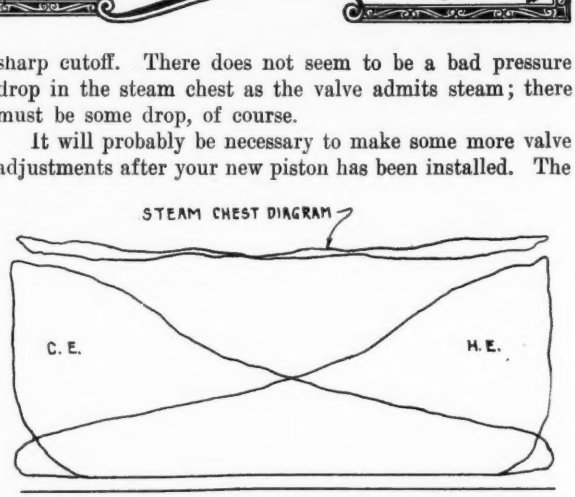
The diagram shows a simple form of single tube injector. Boiler steam admitted at A and, flowing through nozzle C and combining tube D to the atmosphere through G, partially exhausts the air from pipe B, thereby causing the water to rise until it comes in contact with the steam. The steam emerging from nozzle C at high velocity condenses on meeting the water and imparts considerable velocity to it. The steam tube is so shaped that it converts the pressure energy of the steam into velocity energy. The energy in the rapidly moving mass is sufficient to carry it across opening O, lift check H from its seat and force it into the boiler. The steam then ceases to escape at G. Usually a check valve is provided in G which closes when the velocity of the water current causes a partial vacuum in the chamber around tubes D and E.

Indicator Diagram Shows Valve or Piston Leakage

AFTER MAKING some of the valve adjustments on our 20 by 30-in. Corliss that you suggested in the April 15 issue, I took a diagram from the steam chest, according to your directions, as shown. Do you think the pressure drop in the steam chest is too great? We took off the cylinder head and found that the piston was badly worn and leaking, as you suspected. The cylinder will be rebored and a new piston fitted. Do you think it will be necessary to make any more valve adjustments? C. H. S.

A. We believe that after you have put in the new piston your diagram will show a horizontal steam line and a sharp cutoff. There does not seem to be a bad pressure drop in the steam chest as the valve admits steam; there must be some drop, of course.

It will probably be necessary to make some more valve adjustments after your new piston has been installed. The



STEAM CHEST DIAGRAM FROM 20 BY 30-IN. CORLISS SUPERIMPOSED ON CYLINDER DIAGRAM

admission line shown on this diagram is better. Compression seems to be about right on the head end, but release can probably be made still earlier.

Examination Questions

A HEATING SYSTEM carrying 4 lb. pressure has the returns on a level with the water in the boiler. The boiler carries 80 lb. pressure. How can the returns be brought to the boiler with only one trap?

A. The returns in the heating system may be brought to the boiler by having a receiver located two or three ft. below the level of the return system which is on a level with the water in the boiler. The condensate will then flow to the receiver. Next locate a good make of tilting type of boiler return trap 2 or 3 ft. above the water in the boiler. Since there is 4 lb. pressure on the return system, this is ample to lift the condensate from the receiver to the return trap. When the receiver ball of the trap is filled, it tilts and opens the steam valve, admitting steam under boiler pressure.

Pressure on the trap and boiler are thus equalized, and since the trap is 3 ft. above the water line, the water will pass, by force of gravitation, from the trap into the boiler.

2. What advantage has a piston valve over a slide valve?

A. There are five main advantages:

(a) The valve ports may be short and direct.

(b) The clearance volume and area are reduced to a minimum, resulting in a reduction in steam consumption.

(c) Valves are made to operate promptly without loss of power due to wiredrawing.

(d) Closing of inlet valve at point of cutoff is effected in such a way as to leave the points of admission, compression and release unchanged, which permits them to occur at the proper points of the stroke.

(e) The ordinary slide valve has a heavy pressure bearing upon it throughout its travel, causing wear not only on the valve but also of the seat.

3. What precaution should be taken in regard to lead on large vertical engines?

A. On the down-stroke, steam is carried much farther than on the up stroke and the power greatly increased. This is undesirable in vertical engines as the weight of the reciprocating parts acts in the same direction, assisting the steam in the down stroke and resisting in the upstroke. This inequality is adjusted by increasing the steam lap at the top and decreasing it at the bottom and by this means the effect of the descending weights, piston rods, etc., is adjusted to suit the engine balance. This equalization is also frequently accomplished by moving the valve a short distance along the rod toward the top end. The effect of this change is to make the point of cutoff later on the up stroke and earlier on the down stroke. The lead and exhaust lap at the bottom end are increased, thus giving a greater amount of cushioning which counteracts to some extent the weight of the descending parts.

4. Give a reliable method of locating broken staybolts in a Manning boiler without a drilling.

A. Boiler inspectors often use a hammer and can locate broken bolts by sound but this method requires skill and experience not possessed by the average operator.

5. A tandem compound engine will start all right from the bottom quarter but will not start from the top quarter. What is wrong?

A. This seems to be a "catch" question and is open to criticism as a fair examination question. We submitted it to several manufacturers of steam engines and received answers agreeing with our interpretation.

We quote in part from one of the answers:

"Our answer depends to some extent on whether or not we understand the point of the question. The terms, "bottom quarter," and "top quarter," are not common terms in referring to the crank position. We presume that the examiner means by the term, "bottom quarter," a position of the crankpin directly under the center of the shaft and, correspondingly, that he means a position directly above the center of the shaft when he uses the term, "top quarter."

"The writer's answer to such a question would be that the valve of whatever type it might be, or in case of a four-valve engine—the two high pressure steam valves must be off in their adjustment so that steam is admitted properly to the cylinder when the crankpin is at the bottom quarter but is not admitted when the crankpin is in the top quarter.

It is evident that the question is indefinite, since the writer has discussed it with some of our engineers and it has been understood differently by different men."

6. In Diesel engine practice, what is meant by the term, "Brake Mean Effective Pressure?"

A. It is the M.E.P. referred to brake horsepower.

$$\text{Brake M.E.P.} = \frac{\text{Brake hp.} \times 33{,}000}{A \times L \times N}$$

where A = piston area in square inches
L = piston stroke in feet
N = number of power strokes per minute.

7. What are the mechanical reasons for more than one stage on a Curtis turbine?

A. The principal mechanical reason for using more than one velocity stage on a Curtis turbine is to keep the blade speed from becoming too high. On some types of impulse turbines the designers have deliberately employed the high blade speed, using only a single velocity stage and have then proceeded to design the buckets and wheel to take care of the strains set up by this high blade speed. In the Curtis turbine, however, it has been considered advisable to keep this speed as low as possible by using a number of velocity stages.

8. What is the difference between an impulse and reaction type of turbine?

A. In the impulse type the steam is expanded by suitable means and the heat given up by the pressure drop imparts velocity to the jet itself. The jet impinges against the vanes of a rotating wheel and gives up its kinetic energy to the wheel. If the entire pressure drop takes place in one set of nozzles and the resulting jet is directed against a single wheel the turbine is classified with the single-stage single-velocity group. The velocity of the jet is very high, from 2000 to 4000 ft. per se., and for satisfactory economy the peripheral velocity of the wheel must also be very high, from 700 to 1400 ft. per sec. The De Laval "Class A" turbine is the best-known example of this group.

If the entire pressure drop takes place in a single set of nozzles and a single wheel is to be used at a comparatively low speed, satisfactory economy may be effected by compounding the velocity. That is, the jet issuing from the nozzle at a very high velocity is reflected back and forth from the vanes on the rotor to a series of fixed reversing buckets until all of the available kinetic energy of the jet has been imparted to the wheel. The Terry single-stage turbine is representative of this group.

Low peripheral velocity and high efficiency may be obtained by pressure compounding; that is, expansion takes place in a series of successive nozzles instead of one nozzle. Only a part of the available heat energy is converted into kinetic energy in each set of nozzles. For each set of fixed nozzles there is a corresponding rotor. This type of turbine is to all intents and purposes a series of single-velocity impulse turbines placed side by side. The Kerr turbine is representative of this group.

By compounding both velocity and pressure we have the multi-velocity and pressure type of which the Curtis turbine is the best-known example.

In the reaction type the conversion of potential to kinetic energy takes place in the moving blades as well as in the fixed blades. Only an extremely small portion of the heat energy imparts velocity in the first set of fixed blades or nozzles. The jet issuing from this set of nozzles impinges against the first set of moving blades at a velocity substantially that of the moving blades so that it enters them without impulse. The moving blades are proportioned so that partial expansion takes place within them and the resulting increase in velocity exerts a reaction upon the moving blades. The expansion is exceedingly gradual and a large number of alternately fixed and revolving blades are necessary to effect complete expansion. Because of the small pressure drop in each stage low peripheral velocities are possible with high over-all efficiency. The Westinghouse and Allis-Chalmers designs of the Parsons turbine are the best-known examples of this type.

EDITORIAL COMMENT

Designing for Economy Rather Than for Efficiency

Time after time, in these columns, we have reiterated the statement that high plant efficiency does not always result in economy. We know that engineers feel the force of this statement, therefore we wish to call attention to the article on page 630 of this issue in which James A. Powell discusses the desirability of designing power plants for economy rather than for high efficiency. The value of this article is that it illustrates by specific examples the way in which the author applied to an actual power plant problem the fundamental economic principles involved.

In doing this, a study was made of the whole station and of the separate items of equipment. In this study, the load factor, fuel cost, fixed charges and many other factors that have an influence on the design were considered. The curve that shows limits, between which additional investment for greater efficiency or lower operating costs will produce a given return on the additional investment, is simply a graphical representation of the law that the increment of investment necessary to raise efficiency must earn more than its fixed charge in order to justify the expenditure. In considering Mr. Powell's conclusions that, with present costs of fuel and equipment, an attempt to make a kilowatt-hour with less than 16,000 B.t.u. may be a poor business undertaking, it is to be noted that he qualifies the statement by taking into account load factor, local conditions and the like.

It must not be imagined that such a study of the relation between efficiency and economy is an easy thing to make. Data must be obtained—from manufacturers, from existing records, from every available source—and then carefully evaluated, classified and, if possible, plotted. Even then the common sense and good judgment of the designer must be applied to each conclusion. But the result of the work is decidedly worth while. When it is finished, the designer can say with some degree of accuracy just how high an efficiency is worth trying for in the particular plant under discussion, in order that it shall be operated on a business-like and reasonable basis.

Accident Prevention Campaigns Pay

Every man's sensibilities become immune to sentimental influences when he is continually witnessing accidents or the results of accidents. Such things become everyday matters of fact to be expected in our industrial life. Accident prevention needs a stimulus occasionally to keep us alert to the dangers surrounding us. Men seem to delight in seeing how close they can come to having a severe accident, yet miss it.

In the power plant field, we are, in many cases, limited in our use of what are considered to be theoretically ideal conditions by safety considerations. Though we may desire the higher voltage, it is too dangerous in many places. Boiler pressures are limited for the same reason. Furnace temperatures are as high as the materials around them will endure. Turbine and motor speeds are as high as safety will permit. Some pioneering must be done, if the industry is to progress and in such cases accidents are liable to happen but, as a general thing, the large percentage of industrial accidents are the result of human weaknesses rather than failures of equipment.

Most machinery will stand a considerable abuse, far beyond what should be expected of it in operation and the dare-devil operator who finds this out is the one who is liable to reap a harvest of accidents. To curb this spirit and bring men to a realization of their dangerous habits, a number of industries, including power plants, have conducted "no accident month" campaigns.

As usually carried out, the campaign consists of safety lectures, posting of safety bulletins and daily charts showing progress made in avoiding accidents, fostering a competitive spirit among the men at different plants or departments of the same plant and calling the attention of workmen in numerous other ways to the points of danger about the plant and how to avoid accident.

With everybody in the plant thinking and practicing safety, not only are accidents reduced, but the training produces more careful and efficient operators. Such campaigns have proved to be well worth while.

Dipping Into the Future

From time immemorial man has had an innate desire to foretell coming events and in the old biblical days he seemed to take a morbid delight in painting gloomy pictures of cataclysms. No one wasted any energy with prophecies of pleasant things, for anything of that sort was taken for granted. Religion was largely one of fear and men sat up nights figuring what might happen to the evil doer, but didn't bother much about any rewards for the righteous. They had to be satisfied they weren't stoned or boiled in oil, much less think of getting any recognition for good deeds. And so it went on down through the ages, each generation with its goblins and devils but few, if any, with its laurel leaf or blue ribbon.

But gradually the veil of the unknown is being lifted and modern science, fostered under fearfully trying circumstances by such men as Galileo, Michael Angelo, and Descartes, is attaining its laurels.

Today, with a few exceptions, man may not only announce his discoveries without fear of arrest or persecution, but he may go even further. He may link the past and present with the future and, with the centuries of experimentation behind him, offer valuable hints as to what may be expected in the way of invention and discovery.

Many notable prophecies have come true and there are no reasons to believe that others will not. Jules Verne's vision became a reality when the first submarine was launched; Tennyson foretold the coming of the aeroplane and the great World War with its fearful conflicts in the clouds and finally, we hope, his dream of universal peace —the Federation of Man—will become a reality. Tennyson also visioned the possibilities of aerial commerce and

the great freight carrying ships of the air we are now beginning to see soaring over us.

Coming on up to the immediate present, we find the business of being a prophet actually becoming lucrative. Our book shops are beginning to be flooded with books dealing with the future of science. Probably the most notable of these is a book called Daedalus by J. B. S. Haldane, an English biologist and chemist. Engineers who have not already done so are urged to read this remarkable little book. While we do not subscribe to all that he predicts, we see how many things may easily be possible. Today we glibly speak of "super power" and many fondly imagine that in our huge central stations with their high pressures and superheat, we have reached the superlative of power. After reading Daedalus we must realize that our generation of power is only in its infancy.

We have done well, we are progressing, but there are greater heights yet to be reached. Haldane points out that in our production of electric light only 5 per cent of the energy we put into it is utilized for the purpose it was intended and 95 per cent is dissipated in the form of heat. Until we can produce cold light, like the fire-fly, we cannot claim real effectiveness. Men are gradually going back to elemental things. We are now utilizing the great free air above us for a large source of nitrogen needed in fertilizers and Haldane thinks that the great unharnessed force of the wind may be a source of our future power.

It is not difficult to conjure up the possibilities which science will eventually find in the greatest sources of all energy—the sun. Sanitariums are now being fitted with quartz glass windows which do not cut off the ultra-violet rays of the sun which science has found so necessary in the treatment of disease. Solar energy may be the source of other rays, shorter and far more potent than X-rays.

Geologists tell us that the end of the world's oil supply is in sight, but that coal will last many, many years longer. In our pulverized fuel furnaces we are just beginning to realize the possibilities of coal, yet no matter how efficiently we burn it we cannot transform its energy into power without great loss. In our most up-to-date power plants from 80 to 85 per cent of the heat energy in the coal is lost to the condenser water.

Oil engine practice shows efficiencies two to three times as great but, since our oil supply is limited, we will have taken a distinct stride forward when we find means of extracting the heat energy in coal by the use of our present oil engines. The possibility suggests itself that, since powdered coal is quite explosive, the day will come when men will find practical means of burning powdered coal in Diesel engines. Boilers and furnaces will become obsolete.

The spirit of the mythological Daedalus will carry on and on.

Off Duty

It's getting hot again. Soups and heavy meat orders are giving way to salads and iced tea, and strawberry short-cake is the regular dessert. Straw hats have come into their own. The electric fan has been resurrected from its winter quarters and under the soothing influence of a copious squirt of 3-in-1 drones its weary way through the long June afternoon.

Ho hum! Gosh, what shall we write about? We seem to have no more ideas than a grasshopper, and that isn't much. But a grasshopper doesn't have to write Off Duty articles so he has the advantage of us.

What good is a grasshopper anyway?

Well, now, that all depends. A single grasshopper isn't of much use except perhaps to a robin for whom he makes a choice morsel, but when we have a couple of million we can make oil out of them.

Oil? Sure, grasshopper oil. Best thing in the world for lubricating aeroplane engines. Recently, 18 T. of dried locusts, we call 'em grasshoppers, were shipped from South Africa to Holland for the extraction of the oil. This oil is said to retain its liquidity at extremely low temperatures and is therefore very well suited to the use of airplanes in high altitude work.

Now, 18 T. of grasshoppers may sound like a whole lot of grasshoppers, and it is, but compared to the total grasshopper crop it is nothing. Consider for a moment the stories of the grasshopper year in Kansas in 1876, when they came in such countless numbers as actually to darken the land. It is said that they were so numerous that trains passing through that country were stopped due to the greasing of the rails by grasshoppers. That alone speaks well for the use of grasshopper oil as a lubricant.

In a recent number of the Scientific Monthly. Dr. Edwin Slosson refers to other accounts of grasshopper swarms. In the swarm which migrated from Africa to Arabia across the Red Sea on November 25, 1889, it is estimated there were 25 trillion grasshoppers; 44 million tons of them! Covering an area of 2280 sq. mi., they were all day passing a given point. Some grasshoppers! But wait, this is only a teaser.

Another swarm Slosson mentions is that which passed over Pretoria on May 25, 1891. This swarm is more accurately, or at least, more definitely estimated as composed of 130 trillion, 800 billions of individual insects and is said to have filled 12 *cubic miles* of space in the air. In 1866 a swarm invaded Algeria whose weight on the wing was estimated at 50,000 T.

These accounts of grasshopper swarms give us an idea. Why not use grasshoppers for fuel? We don't know the B.t.u. value of a pound of grasshoppers but due to their oil content, it ought to be high.

Considerable apprehension has been felt lately about the rapid depletion of our oil resources. Even our coal supply won't last forever. The use of alcohol as fuel has been suggested but the making of alcohol is a complicated process and its cost would be high. The grasshopper process on the other hand is simple, rapid and effective.

A green crop by virtue of the energy from the sun converts the carbon, nitrogen, hydrogen and oxygen of the air and water into plant protoplasm; along comes a flying cloud and in a few seconds, all this is converted into grasshopper meat, leaving the ground bare. So, why not complete the cycle and, under boilers, convert the grasshoppers into CO_2 by the process of combustion?

Certainly, the production of grasshopper meat is rapid enough. The weight of the Red Sea swam is greater than the weight of all the coal burned in central stations in the United States in a year, yet these grasshoppers were produced in a few week's or a month's time.

Imagine, in the year 2675, seeing, "Grasshopper Fuel Co., Inc., High Oil Content Grasshopper Fuel. Fresh supply raised weekly in our own incubators."

Finish the dream yourself; we don't feel much like work this afternoon.

Ho hum! Wish we were Off Duty.

N. D. H. A. Holds Convention at West Baden

INTERESTING AND PRACTICAL ENGINEERING REPORTS WERE PRESENTED, INTERSPERSED WITH PERIODS OF WHOLESOME PLAY, AT 16TH ANNUAL GATHERING

AT THE WEST Baden Springs Hotel, West Baden, Indiana, from May 19 to 22, the National District Heating Association held its sixteenth annual convention, the morning sessions being devoted to the regular business of the association and to the exceedingly interesting and practical reports of the various committees, the afternoons being spent in golfing tournaments and other sports. A special entertainment program was provided for the ladies, and both men and women took advantage of the splendid recreational facilities for which West Baden is famous. One hundred and six members of the association were registered, their families and friends bringing the total attendance at the convention to 160. On the evening of Thursday, May 21, a banquet was held and the convention came to a close on Friday noon with the election of officers for the ensuing year.

PROBLEM OF CORROSION DISCUSSED

At 10 o'clock on Tuesday, May 19, the first business session was opened with an address by President O. W. Kastens, Grand Rapids, Mich., who presided over all meetings. This was followed by the reading of the reports of the secretary-treasurer, the technical secretary, the executive and educational committees; a nominating committee was also appointed. The report of the corrosion committee of which J. H. Walker, Detroit, Mich., was chairman, was then presented.

In this report, the committee referred to its previous outline of the corrosion problem as encountered in district heating. After discussing in some detail the method of making corrosion tests, used by one of the member companies during the past winter, in several buildings having different types of heating systems, the committee presented the following conclusions: (1) That dissolved oxygen and CO_2 are causes of corrosion in consumers' heating systems; (2) that so far it has not been demonstrated that corrosion is dependent on the type of the heating system, but in general it is obvious that a system is to be preferred that affords less opportunity for aeration of condensate; (3) that corrosion should not take place if the oxygen content is less than 0.5 c.c. per liter and if the PH value is greater than six; (4) that feed-water treatment should, if possible, be so designed as to eliminate CO_2 from the steam, which may be a difficult and costly process; (5) that deaeration of the feed water is desirable but there is still the possibility of aeration of the condensate in the consumers' system. After this report, Professor J. D. Hoffman, Purdue University, delivered an address on "The Engineer as a Community Asset."

As the first paper of the second session on Wednesday morning, the report of the station operating committee was read by its chairman, R. G. Felger, Detroit, Mich. This report consisted of a series of short articles contributed by member companies on various phases of station operation. Such subjects as the following were included: "A Statement on Hydraulic Drive Taylor Stokers," by the Consumers' Power Co., Jackson, Mich.; "Smoke Indicators," "Purification of Gases for CO_2 Machines," and "Refractory Materials," the three latter by the Detroit Edison Co.; several other interesting reports from other companies.

J. C. Butler, Chicago, Ill., chairman of the operating statistics committee, next read its report. This report, based on replies to a questionnaire, gave a summary of classification of customers, methods of metering, steam sold, load factors, evaporation, labor costs and the like. An analysis of the cost distribution showed, according to this report, that for the companies reporting, operating costs averaged 53.1 per cent, maintenance 7.5 per cent, general expense, 4.9 per cent and interest, depreciation, taxes and the like 34.5 per cent. Eighteen companies reported satisfactory experience with welded pipe for underground work; the other twelve companies reporting had had no experience with welded underground piping.

In the address of the morning, L. E. Young, of the Union Electric Light & Power Co., St. Louis, Mo., discussed the general coal situation, bringing out the points that ought to be considered by the district steam heating engineer in establishing his future coal-buying policy.

Mr. Young called attention to the recent American Engineering Council report on coal storage. He then pointed out that the question of future freight rates as well as labor conditions would have an important bearing on the future price of coal. He showed how the wage of the miner had increased, from $3.00 a day for inside work in the mine in 1916 to $7.50 a day in 1920, further extended by agreement to 1927, and pick mining from 60c a ton to $1.04 a ton; the labor cost of coal mining, he said, is about 75 per cent of the production costs. The competition of the steam shovel mines and the rapid introduction of coal mining machinery in underground mines to replace manual labor will have its effect, Mr. Young stated; undoubtedly, though cheaper coal may be obtained, it will be lower in quality and users must be prepared to cope with this condition.

J. E. Seiter, Detroit, Mich., as chairman of the heat utilization committee, presented the report of that committee at the morning session on Thursday, May 21. The report is an analysis of savings made in heating buildings

with central heat by correcting defects in building construction and in heating systems, by rearranging buildings and similar methods. For example, weather strips properly applied have resulted in savings of 11 to 44 per cent in steam consumption; rearrangement of piping systems has effected savings of 10 to 30 per cent; the use of unit thermostats has saved as much as 31 per cent. Many other examples showed the great savings that could be made through co-operation between consumer and producer of district heating steam. The report of the heating research committee, Earle Shultz, Chicago, Ill., chairman, contained an analysis of power and labor costs, based on square feet of rentable area of a number of office buildings. In addition comparative costs of power for buildings having electric elevators showed 18.36 cents per sq. ft. of rentable area when all power was purchased, 19.06 cents when only electricity was bought and 24.8 cents when generating their own power. For buildings with hydraulic elevators, the corresponding costs were 23.0, 28.9 and 28.5 cents, respectively.

District Heating Is Becoming a Public Utility

Mr. Shultz delivered the address of the Thursday morning session, discussing some of the factors that should be considered in expanding a district steam heating enterprise. It was his opinion that only in the business districts is district steam heating profitable. Three reasons for its growth there are: (1) the convenience of the service; (2) the savings possible that cannot be made in the isolated plant, and (3) the investment savings, especially in the case of remodeled buildings or new buildings. The speaker also discussed problems of interconnection with old plants, peak loads, and of making and applying proper rates. His conclusion was that the district steam heating plant is destined to assume a high place as a public utility.

On the last day of the convention, Friday, May 22, the report of the hot water heating committee was read: R. C. March, Chicago, Ill., was chairman of this committee. An address was given by A. C. Marshall, Vice-President and General Manager, Detroit Edison Co. The final report, that of the distribution committee, was read by its chairman, O. W. Kastens, Grand Rapids, Mich. This report contained data from tests on various types of pipe welds made by Prof. Sweetzer of Washington University, together with construction details of the 20-in. steam main, for 250 lb. pressure and 100 deg. F. superheat, installed in St. Louis in 1924. The convention was brought to a conclusion with the election of the following officers for the ensuing year:

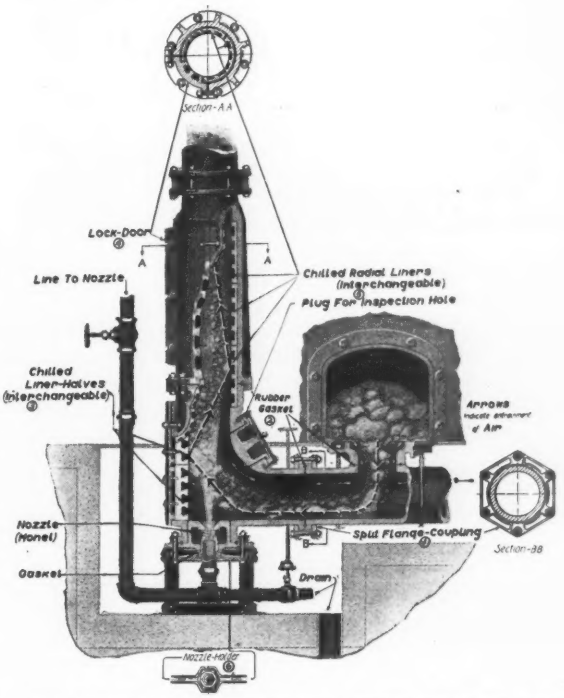
President, Earle Shultz, Illinois Maintenance Co., Chicago, Ill.; First Vice-President, J. E. Seiter, Detroit Edison Co., Detroit, Mich.; Second Vice-President, Chas. A. Gillham, New York Steam Corp., New York City; Third Vice-President, Chas H. Day, Cleveland Electric Illuminating Co., Cleveland, O.; Secretary-Treasurer, D. L. Gaskill, Greenville, O.; Executive Committee, W. W. Stevenson, Allegheny Co. Steam Heating Co., Pittsburgh, Pa.; David Caleb, Kansas City Power & Light Co., Kansas City, Mo.; O. W. Kastens, Consumers Power Co., Grand Rapids, Mich.

One of the interesting features of the convention was the manufacturers' round table discussion held at the close of each regular session. At this time, representatives of various companies were allotted 15 min. each to discuss details of new and useful devices applicable to district steam heating work.

Jet Conveyor Equipped With Rebound Fitting

ECONOMY of steam required by a steam jet conveyor can be obtained only if the joints in the system remain tight. This means that provision must be made for expansion and contraction which will result in all cases because the conveyor is normally cold when not in use. When in use it suddenly becomes heated to the temperature of the steam and the hot ash passing through it. Also, there are always vibrations present which may cause the somewhat brittle white-iron castings to break should the joints be unyielding and rigid.

For these reasons the Hahn Engineering Co. has adopted on its steam jet conveyor the Vanstone type of joint fitted with split flange-couplings of malleable iron. Features



TAPERED INSERTS OF CARBORUNDUM REDUCE WEAR ON LINER

incorporated in this equipment are designated by the numerals on the accompanying cut. They are: (1) Separate flange-coupling of the Vanstone type, acting as expansion-joint to protect the pipe-flanges against expansion and contraction, as well as vibration. (2) Half-inch round rubber gasket securely wedged between flanges, thereby forming an air-tight joint, even though these flanges of hard cast-iron cannot be machine-finished. (3) Liner-halves secured in place by cast-in bolts, thereby preventing frequent trouble in conveyors due to dislocated liners caused by the severe impact of large clinkers. (4) Radial-liners in rebound fitting, which are also exposed to severe impacts, secured in place by a lock door, which also provides access to these liners. (5) Radial-liners afford protection 3 ft. above elbow and take up the wear due to rebounding clinkers from the elbow. (6) Steam-nozzles of Monel metal, easily removable for periodical inspection or replacement by removing two bolts and the nozzle-holder.

New Device Swings Coal Spouts Automatically

DUE TO uneven coal distribution and segregation of particles, when using stationary spouts, operators of chain grate stokers have long felt the need and importance of swinging spouts. Many plants do use this means of coal

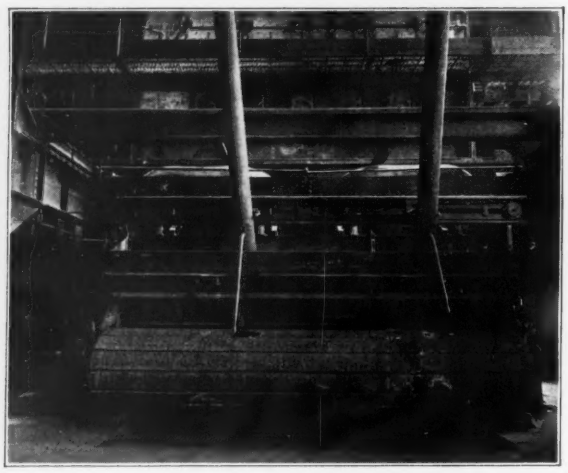


FIG. 1. SWINGING COAL SPOUTS OPERATED BY CHAIN DRIVE

distribution but until recently only manual operation has been employed. To overcome the obvious difficulties of hand control The Henry Pratt Co., of Chicago, is now manufacturing the Phillips coal spout swinger, operated by a chain drive, directly connected to the main drive of the stoker. Figure 1 shows the complete mechanism as applied to a chain grate stoker, 24 ft. wide, and using two swinging spouts. The only connection between the spouts,

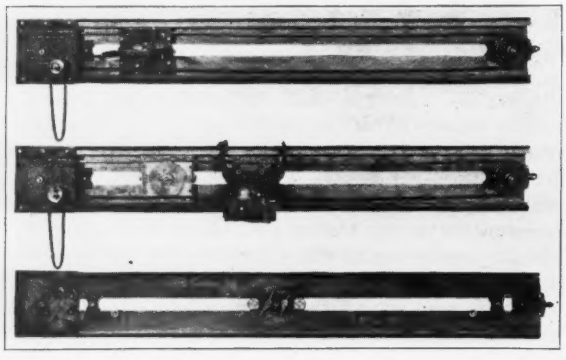


FIG. 2. UPPER VIEW SHOWS COMPLETE ASSEMBLY OF SWINGING MECHANISM. MIDDLE VIEW, WITH YOKE PLATE REMOVED SHOWS REVERSING SPROCKET. LOWER VIEW SHOWS REAR OF ASSEMBLY WITH REVERSING LEVERS AND ADJUSTABLE STOPS

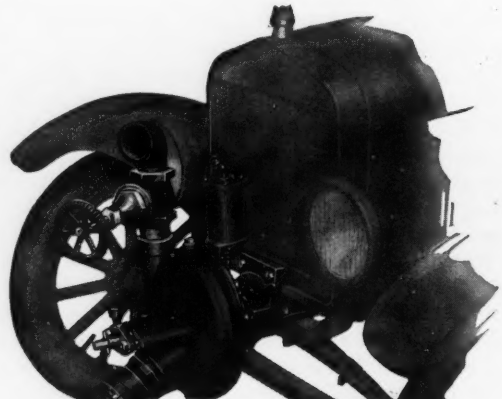
as hand operated; and the power driven mechanism, are the yokes which drop into place around the spouts and which may be hinged up behind the spouts if for any reason it becomes necessary to use hand operation. Just above the aisle, to the left of the stoker, a short roller chain may be seen which is connected to a counter shaft running to the stoker motive power at the rear. When two swinging spouts are used, not much power is required for the operation as the weight of one spout, returning from the end of its arc of swing, helps drive the other one.

In Fig. 2, the upper photograph shows a front view of the complete machine. In the middle the same view is shown, but with the shuttle cover or yoke plate removed to show the reversing sprocket. The lower picture gives a rear view of the machine and shows the reversing levers on the shuttle. Also, there may be seen the adjustable stops which permit change of travel of the shuttle and the adjustable idler sprocket block which regulates the tension of the drive chain.

To reverse the shuttle, the method employed is original, quite simple, and withal, rugged. There are only three moving parts as shown in the middle and lower views of Fig. 2. The middle picture, with shuttle cover removed, shows a special hardened steel sprocket in the form of a pentagon mounted on a central bearing pin. This sprocket has five straight faces and five pairs of teeth on its periphery and the pair of teeth at the extreme top of the sprocket are engaged with the driving chain, while a screw dowel in the dowel hole prevents the rotation of the sprocket. This causes the shuttle to travel in the direction of the top chain and when the shuttle arrives at the end of its travel one of the reverse levers is thrown by the adjustable stop. This causes the withdrawal of the screw dowel and permits the reverse sprocket to revolve, engaging the lower chain and disengaging the upper chain, while the other dowel is forced into its dowel hole and the reversal completed.

Utility Pump Driven from Shaft of Motor Car

PORTABLE PUMPING units using the motive power of cars, tractors or trucks by means of a patented power take-off that connects the pump with the motor are now



PUMP NEED NOT BE REMOVED WHEN DRIVING THE CAR

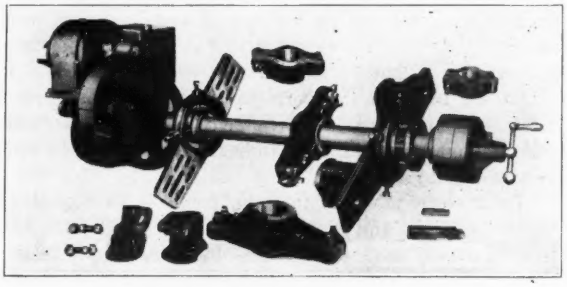
manufactured by the American Steam Pump Co., Battle Creek, Mich. The pump is of the centrifugal type of special design thus affording minimum weight. As the weight of the pump is carried on the frame of the car, it may be left on while driving without strain or break-

age to the car. The pump is driven by means of a floating shaft from the motor. It is made in two standard sizes 2½ and 3-in. The suction hose used on the 2½-in. pump is a 3-in. hose and on the 3-in. size 3½-in. hose, both of standard thread. The 2½-in. pump will lift water over 20 ft. and has a normal discharge capacity of from 200 to 250 gal. per min. at 18 mi. per hr. driving speed. The 3-in. pump has a discharge capacity of about 300 gal. per min. A small hand clutch is used to disengage the power unit while driving. These pumps can be equipped with the Barton automatic primer, which is also manufactured by this concern.

Motor Driven Cylinder Boring Bar

RECENTLY E. J. Rooksby & Co., Philadelphia, Pa., developed and placed on the market a motor-driven portable cylinder and valve chamber boring bar for reboring cylinders and valve chambers of steam engines.

The feature of the design of this machine consists principally of the manner of driving the bar by means of an electric motor. The motor is mounted on a suitable



PARTS FOR COMPLETE ASSEMBLY OF CYLINDER BORING UNIT

base on the gear drive frame, forming an integral part thereof and the speed reduction is accomplished by mechanical gearing. The gear box, having shifting gears, is provided with four or more changes giving the operator a selection of cutting speeds, suitable for all the cylinders of diameters within the range of the bar similar to those obtainable on the best modern machine shop tools. The gears, having a positive locking shifting device, are completely protected, being enclosed in a gear case and run in grease.

These machines are furnished with either d.c. or a.c. constant speed motors. Should a variable speed d.c. motor be desirable, the speed gear box is not required. The main gear drive is provided with safety guards. The bars are made of the best grade open hearth machinery steel accurately finished. Long experience has shown that when it is necessary to use more than one tool at a time, two tools placed on directly opposite sides of the bar produce the best results. A double arm cutterhead is designed to accomplish this. Cutterheads are fed along the bar by a totally enclosed feed box which is automatic and continuous in operation.

The machines are made in all sizes, the bars being 3 in. to 6 in. diameter and designed to bore valve chamber bushings or cylinders ranging from 7 in. to 48 in. diameter.

Death of R. C. Cole

ROBERT CHARLES COLE died May 10, 1925, at Hartford, Conn. He was born in 1881 at New Haven, Conn., and secured his early education in that city, graduating from the Hillhouse High School of New Haven in 1898, and entering the Engineering Department of The Johns-Pratt Co. in 1900. He soon became assistant electrical engineer and then held the position of electrical engineer and in 1922 became sales manager of the electrical division, in which position he continued until his death.

Practically Mr. Cole's entire business career of over a quarter century was spent with The Johns-Pratt Co. He started at a time when enclosed fuse development was in its infancy and progressed with it to the various stages of development, production and merchandising. He showed marked engineering skill and ability as exemplified by numerous new developments and improvements for which he was responsible and was generally regarded as one of the foremost engineering experts on fuse protective, underground distribution and allied arts.

Important work was done by Mr. Cole in the development of the present National Electrical Code Standard for enclosed fuses. He with others developed the Standard under which at present enclosed fuses are produced and under which they are approved by the regulatory bodies.

He was a member of the American Institute of Electrical Engineers, Hartford Engineering Club, Hartford Advertising Club and numerous social and charitable organizations. He is survived by his wife, Edith M., and one son, Edward.

Nordberg Builds New Type Cross Compound Engine

NORDBERG MFG. CO., of Milwaukee, has practically completed an engine for the Dow Chemical Co., which embodies a comparatively new practice in steam engineering. It is cross compound with the high pressure cylinder uniflow and of poppet valve type, and the low pressure the Corliss type. Steam is to be introduced to the high pressure cylinder at 350 lb. pressure and 250 deg. F. superheat and will exhaust to the low pressure at about 150 lb. pressure. This engine will run at 120 r.p.m. and generate 1000 kw-hr. Excellent efficiency is predicted.

WILLIAM CRAMP & SONS Ship and Engine Building Company was recently awarded a contract by the American-Hawaiian Steamship Company which calls for the largest passenger steamship ever built in the United States, the propelling machinery being of the geared turbine type. During the past year the scout cruisers Trenton and Marblehead were delivered to the United States Navy. The motorship Seekonk, in which are installed Diesel engines of the Burmeister & Wain type, is being operated for the Cramp Company by the United American Lines and has proved highly economical and satisfactory. The I. P. Morris department has put in operation the second 70,000-hp. turbine constructed for the Niagara Falls Power Company and has a contract for three large units for the Gifu Electric Power Company of Japan. The Dominion Engineering Works, Limited, of Montreal, has received additional orders for 55,000-hp. turbines for the Queenston-Chippewa Station and the Pelton Water Wheel Company will build two impulse wheels of record capacity for the Southern California Edison Company.

Midwest Power Show Held in Milwaukee

EXHIBITS SHOW TREND OF POWER PLANT PRACTICE

MANUFACTURERS AND EXHIBITORS are to be congratulated on the interesting and instructive display of equipment made at the recent mechanical exposition held in the Municipal Auditorium, Milwaukee, Wis., May 18 to 21. It was the first exhibition of its kind to be held in the Middle West and, coming as it did, at the time of the spring meetings of the American Society of Mechanical Engineers and the American Society of Refrigeration Engineers and the Annual State Convention of the National Association of Stationary Engineers, there was a large number of visiting engineers from all parts of the country to study at first hand the latest developments in the field.

The numerous exhibits served not only as an active catalog of mechanical products and processes but embodied many instructive features as pointed out by the large corps of sales engineers in charge. Everywhere, progress was the keynote, and the earnest desire of manufacturers to follow closely the trend of power plant practice was clearly reflected in their offerings.

Link-Belt Co. had an interesting display of conveying and elevating chains, sections of traveling water intake screens, and various types of power transmission. Of particular interest was the display of idlers for belt conveyors. These were equipped with Timken roller bearings so that friction might be reduced to a minimum.

Allis-Chalmers Mfg. Co. featured several types of centrifugal pumping units, both motor and turbine driven. Historical interest was attached to the 10-hp. Parsons turbo-generator, built by C. A. Parsons, of New Castle, England, in 1885. It is the second turbine built by Parsons. An interesting attraction was a large glass tank for illustrating types of liquid stream flow in hydraulic turbines. The tank was filled with water and red colored carbon tetrachloride was dropped through the water to illustrate the action of the impulse wheel, the hydraucone and the water-wheel. A small steam engine, loaned by Schlitz Brewing Co., also gave color to the exhibit. This engine was built in 1858 to take the place of horses for operating the brewery. In 1879 it was first used for lighting 10 arc lamps.

A new development of the Bethlehem Steel Co. is a new design of pulverizer for coal and other materials. It consists essentially of a heavy cast-iron framework enclosing a horizontal table which rotates slowly beneath crushing rollers, and is surmounted by an adjustable air separation chamber. Any prime mover may furnish the motive power and it is stated by the manufacturers that the operation is so efficient that only 20 hp. is used to pulverize 4 T. of bituminous coal per hour, to at least 75 per cent through a 200-mesh screen.

Fairbanks, Morse & Co. featured an 80-hp., 2-cylinder, solid injection oil engine. It is stated that this type of engine is very popular for the operation of ice-making machinery. Maxim silencers muffle the exhaust so that the engines may be used in residential districts. Ball bearing motors were also displayed.

Riley Stoker Corporation showed moving pictures of the construction and operation of Riley stokers.

Combustion Engineering Corporation had exhibits of several of its products, the more important being a section of tubes of the fin furnace, a section of an air preheater, and several types of stoker grate bars.

A comparatively new type of four-cylinder vertical uniflow engine was shown by the Ames Iron Works. The engine is of 320 hp. and 200 r.p.m. The cylinders are cast in pairs, with one intake and exhaust pipe for each pair. The engine is compact and occupies a minimum amount of floor space. About 20 engines of this type have been installed in the last year and a half.

Conveyors Corporation of America featured its steam jet ash conveyor and dust absorption tower.

A device for recording the level of water in a boiler was displayed by the Hackman Mfg. Co. Signal lights flash and a gong rings in case of high or low water. A duplex fusible plug for boilers was also displayed.

Boylston Steam Specialty Co. displayed a complete line of steam traps, reducing valves and other types of valves.

Simplex Valve and Meter Co. featured its cold water meter which measures flow by means of the venturi tube principle.

Attendants at the booth of the Fuller-Lehigh Co. explained many interesting features of powdered coal equipment, models of crushers and driers and several interesting photographs of burner installations were displayed.

At the booth of the Permutit Co., attendants gave an interesting and instructive explanation of water softeners and the new Ranarex CO_2 indicator and recorder which was on display.

In modern power plants the trend is to higher and higher pressures and higher superheat, making more effective insulation necessary. Johns-Manville, Inc., is meeting the situation by providing various combinations of double-pipe covering of which one of the most effective is an inner section composed materially of diatomaceous earth and the outer covering of magnesia. Various kinds of gaskets and packing were also displayed.

The Wickes Boiler Co. displayed interesting photographs of installations. In addition to the company's standard vertical water tube boiler it is offering a horizontal cross drum type.

At the booth of the Ric-Wil Co., interlocking underground pipe conduit was displayed. This conduit protects the regular pipe insulation.

Schutte & Koerting exhibited a non-scraping parallel disc gate valve for 650 lb. pressure, electrically operated; also an engine stop trip and throttle valve which was electrically operated.

The main feature at the booth of the Ellis Drier Co. was a boiler feed system for draining condensation and feeding direct to the boiler.

Vacuum Oil Co. had an attractive display of oil samples and distributed interesting and instructive booklets on lubrication.

Walworth Mfg. Co. called attention to fittings and valves made of electric steel for high pressure. They have successfully used the X-ray to examine steel castings and so develop uniformity of production.

S. Obermayer Co. exhibited samples of their plastic monolithic furnace lining and cement called Ramtite.

Paige & Jones Chemical Co. displayed samples of the ball form of chemicals used in its feed water treatment.

Sales engineers explained how each sample of water is given individual consideration.

At the booth of the Pennsylvania Crusher Co. models of single roll coal crushers were exhibited. The feature of the exhibit was a working model of a Bradford breaker. Slate, rock and tramp iron are discharged without damage to the machine.

Coal weighing scales were shown by the Richardson Scale Co. A model of an apron feed automatic coal scale was displayed.

Scully Steel & Iron Co. featured its Everlasting Blow-off valve.

Anti friction and bearing metals were displayed by the Magnolia Metal Co.

King Refractories Co. called attention to their Mono Boiler Baffling.

Homestead Valve Mfg. Co. had their lubricated quarter turn valves on exhibit.

Unusually clear cut photographs were displayed by the Heine Boiler Co., showing installations of Heine boilers. Engineers in charge explained interesting details of these installations.

Westinghouse Electric & Mfg. Co., through its agents Julius Andrae & Sons, featured its new air brake safety switch with patented arc quencher. This switch will successfully break direct currents of 400 to 600 amp. and 600 v., in air.

Garlock Packing Co. had an interesting exhibit of its various types of packing and gasket material.

The booth of the Standard Oil Co. was exceptionally artistic in displaying samples of their various oil products.

Sarco Co. featured steam traps and temperature regulators.

Oil filters and a new threadless joint for lubricating pipe systems were featured by Wm. W. Nugent & Co.

Edge Moor Co. had on display a number of excellent photographs of its boiler installations and furnished instructive literature on boiler construction.

Engberg's Electrical & Mechanical Works exhibited a vertical enclosed, self oiling engine often used for stoker drives. They also displayed a d.c. generating set for magnet cranes.

American Schaeffer & Budenberg Corp. had an interesting exhibit of indicating and recording thermometers, temperature and pressure controllers, pressure and vacuum gages and a number of other instruments of like nature.

Crane Packing Co. displayed metallic packing for condenser tubes, centrifugal pumps, engine valves and other power plant equipment.

Soot blowers of different types were displayed by the Bayer Co.

American Arch Co. exhibited a section of its suspended arch.

In addition to its well known makes of CO_2 recorders the Uehling Instrument Co. featured its new combined barometer and vacuum recorder.

Edward Valve & Mfg. Co. showed valves designed to operate at the highest pressures and superheats now used in power plants.

Steam traps were the leading points of interest at the booth of the Illinois Engineering Co.

Valves and packing were displayed by Jenkins Bros.

Plibrico, a jointless, plastic furnace lining, was displayed by the Plibrico Jointless Fire Brick Co. A section of a furnace with the method of building the furnace lining was shown.

Freeman Mfg. Co. called attention to distinctive features of their water-tube and return-tubular boilers.

A uniflow engine of about 600 hp. at 150 lb. steam pressure, 150 r.p.m. with an 18-in. cylinder and 24-in. stroke was the leading feature of the exhibit of the Nordberg Mfg. Co.

Various types of expansion joints were shown by the Ross Heater & Mfg. Co.

S-C Regulator Mfg. Co. displayed its feed-water regulator.

Water heaters were featured by The Sims Co.

Union Iron Works distributed literature on water-tube boilers.

L. J. Wing Co. displayed steam and electrically operated blowers.

At the booth of the General Electric Co. the feature of the display was a surface air cooler for air ventilation of a turbo-generator. Various electrical appliances were also displayed.

A model of its suspended flat arch was displayed by the Brady Conveyors Corp., which also distributed literature on steam ash conveyors.

The Griscom-Russell Co. had an attractive display of oil heaters, air coolers, separators and evaporators.

An outstanding feature of the exhibit of Vilter Mfg. Co. was a 30-T. ice machine. The engine is the four valve type, with a maximum speed of 200 r.p.m.

Grinnell Co. displayed various styles of pipe fittings and accessories.

Liptak Fire Brick Arch Co. displayed a model of its suspended arch.

Foster superheaters and economizers were featured by the Power Specialty Co.

The Wm. Powell Co. had an interesting exhibit of valves.

Republic Flow Meters Co. gave a striking touch to their exhibit by having all of their meters and temperature recorders mounted on one large panel.

Hawkeye Compound Co. called attention to their boiler compounds.

Standard Turbine Co. pointed out advantages of its steam turbines and pumping units.

Marion Machine Foundry & Supply Co. featured its hand fired stoker, soot blowers and coal handling machinery.

Casey Hedges Co. showed interesting photographs of its water-tube boiler installations.

Steam traps were featured by the Armstrong Machine Works.

Chapman Valve Mfg. Co. exhibited its Chrome-nickel-steel valves.

Vulcan Soot Cleaner Co. displayed soot blowing units.

Manistee Iron Works Co. gave information on its single and multi stage centrifugal pumps and rotary jet condensers.

Detroit Stoker Co. displayed a single retort and the gear transmission of a stoker. All bearings are fitted for Alemite high pressure lubricator.

Erie City Iron Works distributed catalogs on its pulverized fuel apparatus, steam engines and water-tube boilers.

At the booth of the Dearborn Chemical Co. engineers in charge gave instructive talks on its method of feed water treatment.

M. H. Detrick Co. exhibited its method of installing suspended arches.

The Lunkenheimer Co. had an interesting display of valves.

One of the new features of the show was exhibits of new types of fire inspection doors, by the Vastine Sales Corporation. The outer panel contains blue glass and the glass is kept from cracking by a special grid construction which dissipates the heat. Cooling is also effected by either natural or forced draft.

Other manufacturers represented were as follows:

Allen & Billmyre Co., Inc.
American Asphalt Paint Co.
American Electric Motors, Inc.
American Machinery Co.
American Metal Products Co.
American Resistor Co.
Bartles Maguire Oil Co.
S. F. Bowser & Co., Inc.
Builders Iron Foundry
Burke Electric Co.
Calebaugh Self Lubricating Carbon Co.
Carbon Engineering Co.
Carrick Engineering Co.
A. W. Cash Co.
Cement Gun Co.
Centrifix Corporation
Chain Belt Co.
Chicago Chemical Co.
Chicago Rhopac Products Co.
Chicago Wilcox Mfg. Co.
Cokal Stoker Corporation
Consolidation Coal Co.
Cooper Hewitt Electric Co.
Crandall Packing Co.
Crane Co.
Cutler-Hammer Mfg. Co.
Diamond Power Specialty Corp.
Drying Systems, Inc.
Durametallic Corp.
Electric Service Supplies Co.
Electrical & Steel Sales Co.
Erie Engine Works
Esterline Angus Co.
Fafnir Bearing Co.
Falk Corporation
Filer & Stowell Co.
Foote Bros. Gear & Machine Co.
France Packing Co.
Garratt-Callahan Co.
Alex Goethel Sheet Metal Works Co.
Graver Corporation
A. P. Green Firebrick Co.
Joseph W. Hays Corp.
Heat Sealing Kant Burn Co.
Henry Vogt Machine Co.
Hill Pump Valve Co.
B. Hoffman Mfg. Co.
Howell Electric Motor Co.
Industrial Controller Co.
International Filter Co.
International Nickel Co.
Insulating Products Co.
D. O. James Mfg. Co.
W. A. Jones Fdry. & Machine Co.
S. T. Johnson Co.
Kearney & Trecker Corp.
Keasbey & Mattison Co.
M. W. Kellogg Co.
Kelly Valve Co.
Kempsmith Mfg. Co.
Kent Lubricating Co.
Key Boiler Equipment Co.
La Bour Co., Inc.
Layne & Bowler Co.
Leather Belting Exchange
Lewis M. Ellison
Liberty Electric Corp.
Lincoln Electric Co.
Liquid Carbonic Co.
Lynch, Clarisey Co.
Manning, Maxwell & Moore, Inc.
Midwest Air Filters, Inc.
Midwest Piping & Supply Co.
Milwaukee Electric Tool Corp.
Milwaukee Steam Appliance Co.
Mueller Boiler Compound Co.
Mueller Co.
Northwestern Mfg. Co.
Oilgear Co.
Perolin Co. of America
W. H. Pipkorn Co.
Pittsburgh Valve, Fdry. & Construction Co
Reading Steel Casting Co.
Reed Air Filter Co.
Reeves Pulley Co.
Ricketson & Schwarz
Riley Fredericks Co.
Shallcross Control Systems Co.
Snap-on Wrench Co.
Strom Ball Bearing Mfg. Co.
The Louis Allis Co.
The Badenhausen Corp.
The Wm. Clasmann Co.
The Dravo Co.
The Ehret Magnesia Mfg. Co.
The Ramsey Chain Co., Inc.
Topp Oil & Supply Co.
Trico Fuse Mfg. Co.
Union Steam Pump Co.
Viking Pump Sales Co.
J. H. H. Voss, Inc.
Westco Chippewa Pump Co.
Wisconsin Face & Fire Brick Co.

Paper Corporation Forms Power Company

OFFICIALS OF the International Paper Co., Pershing Square Building, New York, have organized a new subsidiary to be known as the International Hydro-Electric Corporation, to take over and operate the power stations now in service for paper mill operation. The present hydro-electric generating plants of the parent company have a rated output of 180,000 hp., while existing undeveloped water power sites are sufficient to increase this capacity to more than 600,000 hp. The subsidiary organization will not engage as a public utility, simply operating for the interests of the paper company. It is purposed to expand the present power facilities in the near future, including, as well, the construction of transmission lines. This work will also be carried out for paper mill service of the parent company in Canada.

CONTRACT HAS RECENTLY been awarded to William B. Scaife & Sons Co., Pittsburgh, Pa., by the Carnegie Steel Co. for an intermittent water purifier system having a capacity of 2,500,000 gal. per day for its Farrell, Pa., works. A similar plant has been purchased by the Carnegie Steel Co. for its plant for Lucy Furnaces, Pittsburgh, Pa., the supply being taken from the Allegheny River.

Hold Formal Opening of Crawford Ave. Station

CRAWFORD AVENUE Generating Station, the latest addition to the Commonwealth Edison Company's system, was formally opened on Tuesday, May 26. With an ultimate capacity, estimated at from 750,000 to perhaps a million kilowatts, this station, when completed, will rank as one of the largest steam electric plants in the world. The total capacity of the three units now in operation is 160,000 kw.

Included in the 353 invited guests who made the inspection trip at the opening were a representative group of city, county, and state officials, prominent local engineers and financial men, a few visitors from foreign counties and about 150 employes of the Commonwealth Edison Co.

A special train had been chartered to convey the guests to the plant and return them after they had been taken through the station and had partaken of an excellent luncheon. Favors in the form of attractive Morocco leather bill folds were at each guests place and signature cards were filled out for the station's permanent visitor file.

In an address following the luncheon, Samuel Insull, president of the Commonwealth Edison Co. stated that $22,000,000 had already been invested in the station. Its present capacity of 160,000 kw. will in the near future be increased by the addition of a fourth unit of 77,000 kw. capacity. These four units will have an output of about one and one-quarter billion kilowatt-hours per year and will require the consumption of something like 60 carloads of coal a day. Based on the fuel consumption of the other large stations of the company, Crawford Avenue will effect a saving annually of 300,000 T. of coal.

This station will be fully described in an early issue of Power Plant Engineering.

AMERICAN INDUSTRY is making big strides in increasing its efficiency. More goods are being turned out with less labor and, particularly since the war, also with proportionately less machine power. The amount of labor and installed primary power since 1914 has definitely decreased in proportion to the volume of production, owing largely to increased efficiency in management and technical labor saving improvements, in the view of the National Industrial Conference Board. The volume of production, according to a chart prepared by the Conference Board, during the last quarter century (1899 to 1923) has increased 185 per cent, while the number of wage earners during that time has increased only 90 per cent; installed primary power going into the productive process, during the same period increased 236 per cent. The increased use of machinery, however, does not tell the entire story, for, according to the chart, installed primary power and labor employed both dropped off in proportion to the volume of production since the year 1914. This, in the view of the Conference Board, indicates that administrative and technical improvements in the utilization of both labor and power are playing an increasingly important part in the growth of production.

ALTHOUGH American homes which are electrically lighted already number nearly 12,000,000, electrical forecasters are predicting that by 1930 this number will have increased to 16,000,000, or more than two-thirds of the estimated total number of homes in the nation.

Dead Mail Is Expensive

LAST year 21,000,000 letters and 803,000 parcels went to the Dead Letter Office of the U. S. Post Office Department. All this miscarriage, we are told, could be avoided if each piece of mail carried a return address and if each parcel were wrapped in stout paper and tied with strong cord. Postmaster General New stated recently that offenses against good mailing practices are not confined entirely to the average man who mails only his yearly quota of 112 letters. The business man often falls woefully short in providing adequate safeguards for the efficient delivery of his mail.

As to the expense to the sender of improperly addressed mail, the Government states that $55,000 in cash and $12,000 in stamps are removed annually from misdirected mail and $3,000,000 in checks, drafts and money orders never reach their intended owners. To prevent these losses, the first precaution is to be sure that your return address is on the letter or parcel. This should include the name of the sender, city, state and street number or post office box number. The address on the mail should include similar information in regard to the addressee. Advertisers in magazines and newspapers will do well to include their street addresses in their advertisements. If a letter is worth sending, it is worth addressing properly.

Additional Utilities Acquired by Indiana Company

THE CALUMET GAS & ELECTRIC CO., Gary, Ind., controlled by the Insull interests, Chicago, Ill., has secured permission from the state public service commission to take over six privately owned electric light and power utilities, including the Indiana Electric Utilities, Angola, $310,141; C. F. Cain Power & Light Co., Ontario, $159,-188; Hawk Brothers Milling Co., Mongo, $86,382; Bass Lake Electric Light & Power Co., Bass Lake, $19,980; Orland Light & Power Co., Orland, $23,000; and the Nevada Mills Electric Co., Nevada Mills, $33,083. The figures noted are those fixed by the commission as the purchase prices.

Contract Placed for Large Generator

THE BROOKLYN EDISON CO., Brooklyn, N. Y., has contracted with the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., for a steam turbo-generator for its new generating station on Hudson Avenue, said to be the largest such unit ever constructed. It will develop a capacity of 80,000 kw., which is approximately 10,000 kw. larger in rating than other power units now in service. The generator will be 67 ft. 6 in. long, 36 ft. wide, and 24 ft. 6 in. high; it will operate at 1800 r.p.m., and is estimated to weigh 1,835,000 lb. The new unit is said to cost approximately $1,000,000.

CONVEYORS CORPORATION of America, Chicago, Ill., has recently issued a descriptive report covering the fifth steam jet ash conveyor installation made by that company for the Illinois Central Railroad. This latest installation was made at the terminal power plant, Mattoon, Ill.

REINFORCED CONCRETE tanks with water seals have been successfully utilized for the underground storage of fuel oil.

News Notes

UHRICH SUPPLY CO., 914 Central St., Kansas City, Mo., has been appointed representative of the Reliance Gauge Column Co., of Cleveland, O.

R. J. S. PIGOTT has resigned his position with Stevens & Wood, Inc., and is now consulting mechanical engineer for the Public Service Production Co. of New Jersey.

KIELEY & MUELLER, of New York, has recently announced the appointment of C. H. Dutcher to the position of manager. Mr. Dutcher has been associated with Kieley & Mueller for the last five years.

THE TERRY STEAM TURBINE CO. announces the appointment of C. F. Henderson, Call Building, San Francisco, Calif., as the sales representative of this company in the district surrounding San Francisco.

STEARNS CONVEYOR CO., of Cleveland, has just opened a branch office for the sale of material handling equipment in Kansas City, Mo., at 3233 Roberts St. R. J. Hanna has been put in charge of this office.

REPUBLIC FLOW METERS CO. announces the opening of a new factory branch office at 617 Engineers' Building, Cleveland, Ohio. The office will be in charge of L. C. Wilson, formerly of the Pittsburgh office of the Republic Flow Meters Co.

RILEY STOKER CO., LTD., London, England, has recently completed negotiations, whereby Riley, Jones, Murphy and Harrington stokers will be made and sold in Germany by the Deutsche Evaporator-Aktiengesellschaft of Berlin, Germany.

STEPHENS-ADAMSON MANUFACTURING CO., of Aurora, Ill., has established a new sales engineering office in San Francisco under the management of Charles E. Bruff, formerly of the mining engineering firm of Bradley, Bruff and La Barthe. The office will be located at 621 Wells Fargo Express Building.

ANNOUNCEMENT COMES to us that the Sharples Specialty Co. of Philadelphia has opened a new offices at 688 Howard St., San Francisco. The office will be known under the name of "Sharples Specialty Co. of California." L. A. Taylor, who is well-known among the coast industries, will be in charge of the office.

A NEW FOUNDRY FOR THE manufacture of "Ansco" manganese steel castings has just been placed in operation at Los Angeles, Cal., by the American Manganese Steel Co., of Chicago Heights, Ill. This new plant is the most recently established unit of the chain of six foundries now owned by that company, the others being at Chicago Heights, Ill., New Castle, Del., St. Louis, Mo., Denver, Colo., and Oakland, Calif. The organization has facilities for producing about 25,000 T. of manganese steel castings annually.

ANOTHER 35,000-KW. turbine-generator, the third so far this year, has been ordered by the Toho Electric Power Co. of Japan from the International General Electric Co. The last is for installation in the Nagoya station and duplicates the one ordered last year, giving that station a capacity of 70,000 kw. The rating is 35,000-kw. (43,750-kv.a., 80 per cent p-f.), 11,000-v., 3-phase, 60-cycle, 17-stage. The stator will be shipped minus punchings. These, together with the windings, will be assembled at the des-

tination. This same procedure was carried out with each of the other three units.

Dr. Michael I. Pupin, Professor at Columbia University, N. Y., was elected president of the American Institute of Electrical Engineers at the annual business meeting held in New York, Friday, May 15. Other officers elected were: Vice-Presidents—Arthur G. Pierce, Cleveland. O.; W. E. Mitchell, Birmingham, Ala.; Herbert S. Sands, Denver, Colo. (re-elected); P. M. Downing, San Francisco, Calif.; W. P. Dobson, Toronto, Canada. Managers—M. M. Fowler, Chicago, Ill.; E. C. Stone, Pittsburgh, Pa.; H. A. Kidder, New York. Treasurer—George A. Hamilton, Elizabeth, N. J. (re-elected).

Catalog Notes

Roller-Smith Co., of New York City, has just issued two bulletins covering two lines of apparatus manufactured by this company. Bulletin 400 covers two lines of small direct current panel type instruments which employ the d'Arsonval mechanism and are intended particularly for radio sets. Supplement to Bulletin 530 describes the new non-closable overload circuit breaker recently gotten out by this company.

The Griscom-Russell Co., of New York, is sending out a leaflet known as Form 400, describing the G-R Multiscreen filter, which has a filtering surface of 250 times the area of the water inlet passage. This filter is designed for the efficient removal of oil, grease, mud, sand and other foreign matter from condensed steam or raw water to be used for boiler feed or manufacturing purposes.

"Modern Methods in Diesel Engine Building" is the title of Bulletin 1040, just issued by Fairbanks, Morse & Co., of Chicago. The bulletin deals with such subjects as factors affecting quality, selection of material, specifications for steel, forged plants, work in the forge shop, methods of an unusual foundry, finishing of parts, completing the engines, and application and service. It is well illustrated with views in the factory which are attractively presented in colors.

The Brady suspended flat arch is described in a well illustrated pamphlet issued as Bulletin 20 by The Brady Conveyors Corporation, Chicago, Ill.

"Sectional Boiler Fronts" is the title and subject of an interesting bulletin issued by the McClave-Brooks Co. of Scranton, Pa., which shows the various types made by this company and their application to boilers.

The Strong, Carlisle and Hammond Company of Cleveland, Ohio, has just issued Bulletin No. 1, describing Mac-it screws. The catalog, besides illustrating the various styles made, also gives tables showing the sizes of screws and the threads per inch.

Type 2-A of McClave shaking and cut-off grates are illustrated and described in a bulletin recently issued by the McClave-Brooks Co. of Scranton, Pa. The bulletin shows in detail the various parts of the grate and its method of operation.

"Clean Water" Intake Screens is the title of a new book just issued by the Link-Belt Co., of Chicago. This book is well illustrated with views of various Link-Belt water screen installations and contains a brief description of the various types manufactured by that company.

Hercules floats are described in a catalog issued by the Hercules Float Works of Springfield, Mass. The catalog also contains a table showing standard sizes, weights and buoyancies of seamless copper ball floats which is of convenience to the engineer in ordering such equipment.

Milwaukee's sewerage disposal plant is described in a booklet recently issued by the Conveyors Corporation of America, Chicago. The booklet describes in detail the steam jet conveyor used in handling both soot and ashes and is illustrated with halftones and diagrams showing just how the conveyor looks as installed in the plant.

The M. A. Hofft Co., Indianapolis, Ind., has just issued a catalog entitled "Stop Fuel Waste by Installing the National Stoker." This catalog describes in detail the construction features of the National stoker and illustrates with wash drawings and line cuts the action of the stokers.

Bulletin 41 entitled "Water Vs. Steam for Water Gas Making," issued by the Steere Engineering Co., of Detroit, Mich., is an eight-page bulletin and discusses the production of water gas directly from water without the use of steam. It is illustrated with diagrams showing the operation of Steere gas producing equipment.

Yarnall-Waring Co., Philadelphia, Pa., is distributing a celluloid sliding model of the new design of Yarway type B, balanced, seatless blowoff valve. This valve has been developed especially for use on high pressure boilers operating at from 250 to 650 lb. working pressure. The company will be glad to supply anyone interested in boiler blowoff valves with one of these sliding models.

The "Quick Trip" Graphic Meter is described in Bulletin 525 just issued by The Esterline-Angus Co., Indianapolis, Ind. This instrument automatically increases the rate of boiler feed from inches per hour to inches per second in a twenty-fifth of a second. It will also restore the hourly chart speed, resetting it at the proper time on the chart when the disturbance is over.

Catalog Z-2, recently issued by the Liberty Manufacturing Co., Pittsburgh, Pa., is descriptive of the line of Liberty tube cleaners which is issued in all sizes and types of boiler tubes, arch tubes of locomotives, pressure stills in the oil refineries and many other services which require the cleaning of scale or other deposit from tubes or pipes. The catalog describes the construction of the various types of cleaners in detail.

Bulletin 41,521-B, just issued by the General Electric Co., is entitled "High Speed Induction Motors and Frequency Changers." It presents a complete line of motors, alternators and frequency changers adaptable for application on modern high speed woodworking machines and for those forms of machine tools requiring high speed drive. The book is well illustrated with photographs, diagrams and tables.

The Electric Control & Manufacturing Co., Cleveland, Ohio, in its Bulletin 1048 describes a new push button operated oil switch for starting squirrel cage motors and also single phase motors. The starting switch throws the motor across the line when the start button is pushed and is arranged for no-voltage protection or no-voltage release, as desired. Overload and phase failure protection are provided for by means of expansion wire temperature relays.